The Dock and Harbour Authority

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Editorial Comments

Cardiff.

A dozen years have elapsed since in 1926, we gave some detailed account of the great Welsh port and metropolis which stands on the banks of the River Taff and sends enormous quantities of coal, together with steel rails, tin-plates and other manufactured products to all parts of the globe. Our readers, and especially those of Welsh nationality, will welcome, therefore, the article appearing in this issue with an illustrated Supplement, bringing the previous information up to date and setting out the progress which has been made during recent years.

A flourishing port, equipped with the most modern installations for handling its characteristic exports, it is difficult to realise that Cardiff has a history dating back to Roman times. Indeed, tradition asserts that the settlement traded with Greece long before the first Roman invasion of Britain. Prior to that epoch, the myths of legend associate it with certain exploits of King Arthur and his Knights of the Round Table. How far such stories have evidential value is a matter for speculation, but the antiquity of the place cannot be doubted. Historical records show that a castle was constructed by William the Conqueror, and in 1108, Robert, Duke of Normandy, taken prisoner by his brother Henry I., was imprisoned there till his death in 1134.

Cardiff, however, has only attained its commercial importance within modern times. At the commencement of last century it had a population scarcely reaching a thousand, and it was not even entitled to the status of an independent port. It was merely a "Creek," included within the jurisdiction of the great Port of Bristol. The inception of its prosperity and influence dates from the activities of the second Marquis of Bute who, just a hundred years ago, constructed a dock for the development of the coal industry on his estate and, thereafter, the port and town expanded with steady progress until at the present day Cardiff, with its population of nearly a quarter of a million, and a dock system among the finest in the world for its particular trade, ranks in the forefront of British ports, and is the great commercial, cultural and educational centre of South Wales.

Coal and Cardiff are almost inseparable terms, and certainly without the vast coal resouces of South Wales, Cardiff could not have reached the prominence which it now enjoys. Obviously, therefore, the fluctuations of coal exports must have their effect on the prosperity of Cardiff, and this has been very noticeable during the years succeeding the Great War. In 1913 the British exportation of coal (in bulk and bunkers) totalled 94½ million tons. By 1920 it had shrunk to 35½ million tons. There was a revival peak year in 1929, when the figure rose 66½ million tons, but latterly the quantity has again fallen, and now fluctuates between 40 and 45 million tons. For some time Cardiff was adversely affected by the state of the Italian market. Before the War, 90 per cent. of the coal imported into Italy was British. Owing to heavy deliveries of "reparation" coal by Germany and, in part to the extensive development of hydro-electric power in northern Italy, the percentage of British trade fell to 55 per cent., but there has since been a partial recovery, and the re-establishment of friendly relations with Italy will, it is hoped, eventually lead to further improvement.

Our comments on the Port of Cardiff have naturally been based on its commercial and shipping activities. But we should be doing an injustice to a great modern city, if we failed to allude to the impressive civic centre which has sprung up in the heart of the town and which, not less than the dock system, excited our admiration and interest during a recent visit to the port. The magnificent Town Hall, University College and Museum constitute a nucleus of noble buildings of which any city would be proud, and indicate a spirit of corporate enterprise, which augurs well for the further advancement in dignity and importance of the metropolis of South Wales.

The Baltic Conference.

Although principally and essentially concerned with questions and problems relating to shipping, chartering of vessels and the overseas conveyance of goods, the Baltic and International Maritime Conference at their annual meeting on June 2nd, at Stockholm, naturally touched on matters more or less affecting port management. The retiring President, Major Russell Cairns, of Newcastle, in his address specifically alluded to the attitude of port authorities towards shipowners. He said that, in his opinion, port facilities had, on the whole, lagged behind the development of the modern ship. He thought the members of the Conference were entitled to expect from port authorities and merchants a very great deal more in the way of modernising of customs and general speeding up of quayside operations. He further suggested that port authorities could give very material assistance in the form of longer notice of tariff changes. He pointed out that ships were frequently chartered many months ahead, and that a six months' notice of projected changes would be highly beneficial.

No doubt a good deal of Major Cairns' criticism was due to his point of view and the special character of the Conference, but there is much to be said in support of his animadversions on port customs and their obsolescence. There is more or less a general admission that a number of port customs are vexatious and productive of unnecessary delay. The Conference were certainly convinced on the point, and the members subsequently carried a resolution proposed by Mr. Dekkers, of Rotterdam, to the effect that a charterer, shipper or receiver should not be permitted to make the contract of affreightment more onerous to shipowners by imposing on them conditions not expressly or by implication incorporated in their contract.

A further statement in Major Cairns' address was the desirability of an improvement in trading conditions by way of a uniform basis of charging port dues. He was afraid that this was of the nature of a "merely Utopian aspiration." Whether this is indicative of a hopeless resignation to circumstances or not, the fact remains that a good many other people, besides shipowners, are exercised by the anomalies of port charges, and our readers will have in mind the appeal made by Mr. Hopperton, General Manager of the Port of Ardrossan, in his recent Paper on Harbour Accommodation, to the Institute of Transport to recommend the Dock and Harbour Authorities Association to call a conference with the object of defining basic principles for the imposition of dues. Perhaps without waiting for the representations of the Institute, the Association may see the desirability of taking action in the matter forthwith, for it is a condition of things which undoubtedly reflects on the common sense of the mercantile community and of those who administer port affairs.

Editorial Comments—continued

Maryport Harbour Affairs.

The finances of Maryport Harbour have for some years past been a matter of serious concern to the Harbour Commissioners. The place has suffered as a result of prolonged trade depression and, in addition, there has been severe damage to the harbour itself by a series of gales involving repairs which are beyond the resouces of the Commissioners to carry out. A grant was made in 1935 by the Commissioner for the Special Areas to enable the entrance to the harbour to be dredged, but this proved to be merely a temporary palliative, and subsequent gales have caused fresh siltation with destruction of the protective works to such an extent that shipping is reluctant to visit the port.

The position was becoming desperate, and there was every prospect of the closing of the harbour with the loss of its trade and the probable widespread extension of unemployment in the surrounding district. Under such circumstances, the Government have felt justified in intervening, and the Minister of Labour recently announced in the House of Commons a proposal to offer the Harbour Commissioners a sum not exceeding £75,000, in order to carry out the necessary repairs and restore the harbour to a condition of working efficiency. Of the actual expenditure incurred, one-third is to be by way of free grant and the balance by way of loan. The offer has since been accepted.

The principle of State aid for harbours and ports in this country has never been conceded as a general practice. Grants have been made for many years to a number of small fishery harbours, which themselves were incapable of raising locally the sums necessary for harbour maintenance and repairs, but as regards commercial ports with their difficult and complicated problems of trade rivalry, with the exception of certain grants, such as those made under the Trade Facilities Act, as a means of counteracting unemployment, there has hitherto been an abstention, for obvious reasons, from according financial assistance which might imply favouritism and partiality.

The case of Maryport therefore is somewhat of a precedent, though few will grudge the extension of a helping hand to a meritorious undertaking in difficulties which are the result of persistent misfortune. Furthermore, there is the prospect that the rehabilitation of the harbour may foster the development of the coal industry in the neighbourhood and so increase the scope of employment for the inhabitants. If the colliery companies on the Cumberland coast can be assured of the efficiency of the means of export, there is a likelihood that further shafts will be sunk and the output increased. A number of industrial developments are also considered possible of materialisation. Altogether, the situation is one which justifies the exercise of courageous optimism, and the action of the Government is not likely to meet with much adverse criticism.

The Driving of Reinforced Concrete Piles.

The driving of reinforced concrete piles is one of the commonest processes in connection with modern constructional work in ports and harbours, yet despite the wide range of experience gained and the quantity of literature on the subject which has been published, few engineers have felt confident that the methods employed and the standard of penetration attained are entirely satisfactory. In an endeavour to secure an adequate "set," there have been frequent instances of over-driving, which, if they have not disclosed actual rupture of the pile and dislocation of the reinforcement, at any rate must have left an uneasy feeling in the minds of those concerned that all was not as it should be.

As the outcome of investigations carried out at the Building Research Station of the Department of Scientific and Industrial Research, a theory has been formulated which explains the phenomena observed during a series of driving tests and has made it possible to construct charts for the guidance of those engaged in pile-driving operations, in order to safeguard the pile from excessive driving stresses.

In this issue we publish a summary of the Report issued by the Department and commend the entire publication to the careful study of our readers, who will doubtless find the theory elaborated therein of considerable assistance to them in diagnosing the cases of failure where such, to their knowledge, have occurred. The publication also gives definite recommendations as to the manufacture, handling and driving of reinforced concrete piles.

The Lesser Ports.

In the course of his broadcast "talk" on Seaports on June 9th, in the National Programme of the British Broadcasting Company, Sir David Owen, the retiring General Manager of the Port of London Authority, returned to the topic of the Lesser Ports and their trade. On this phase of his subject his remarks were directed against any artificial stimulation of the prosperity of small ports, presumably in the way of grants and subsidies. While admitting that such ports had an importance, yet, if from economic causes the trade of some of them declined then their revenue was reduced and they gradually fell into disuse. He pointed out that the shipping commerce of the United Kingdom was concentrated in comparatively few big ports, leaving numerous small ports with a trifling volume of traffic.

This may be so, but we do not consider it altogether a justifiable argument for the elimination of the competition of the small ports for such trade as is available, though this, no doubt, is to the dissatisfaction of their larger neighbours. The tendency nowadays is, unquestionably, towards the concentration of public services in single undertakings of large size. Nevertheless, there is a risk that the movement may be carried too far and that concerns may be amalgamated to such an extent as to become unwieldy. As regards the smaller ports and harbours, these serve a useful purpose in providing alternative accommodation, which, in time of war, may prove of no little value. It has been announced in the press that the Minister of Transport has under consideration a plan for the diversion of shipping, in the event of the outbreak of hostilities, from the East to the West Coast, and the distribution of imports among Western ports. Should such a course regrettably prove necessary, every available quay will undoubtedly be requisitioned. Furthermore, while deprecating a policy of systematic subsidy on an extensive scale, we feel that, as in the case of Maryport mentioned above, there are occasions on which a helpful grant may be judiciously made, not merely for local salvation, but for the benefit of the community at large.

Sir David mentioned the interesting fact that, apart from one or two ports used solely for naval purposes, there were in the United Kingdom about 330 ports available for mercantile ships. One must admit that among these there may be cases of redundant accommodation, resulting in unremunerative expenditure in equipment and service. Yet it would be unfair to stifle the enterprise of the majority of them in the interests of the great ports, some eight of which share between them one-half of the total sea-borne traffic of the country .

Insect Depredations in Grain Stores.

The enormous losses in this country, estimated at not less than half a million pounds sterling annually, due to the destruction of stored grain and grain products by insects, has given rise, at the instance of importers and warehouse-owners to the institution of a scientific survey to be undertaken forthwith, during the period of seasonal activity of the insects, under the auspices of the Department of Scientific and Industrial Research by the Stored Products Laboratory of the Imperial College of Science and Technology. The matter naturally affects port authorities in connection with their grain silos and warehouses, and it was for this reason that a meeting on May 26th of the Conference formed to co-operate in the work was attended, amongst others, by representatives of the Port of London Authority, and of the London Association of Public Wharfingers, as well as of Government Departments, including the Ministry of Agriculture. The Conference passed a resolution commending the support of the Investigation to the earnest consideration of all sections of trade and industry which suffer from the destruction by insects of stored grain and grain products. Any organisation or undertaking wishing to co-operate in the work should communicate with the Secretary of the Department of Scientific and Industrial Research.

The International Engineering Congress.

It was a happy idea to take advantage of the Empire Exhibition to hold the recent International Engineering Congress at Glasgow. Glasgow, itself, is so important a centre of engineering activities of the most varied kinds, that, coupled with an exhibition which displays so many products and manufactures of a world-wide empire, it could not fail to offer very alluring attractions to the great fraternity of engineers invited to the banks of the Clyde from all parts of the world. Shipbuilding, port appliances and equipment, iron and steel manufactures, locomotives and railway rolling stock, electrical power generation and many other industrial and commercial undertakings provided an extensive field for inspection and observation, of which full advantage was taken.

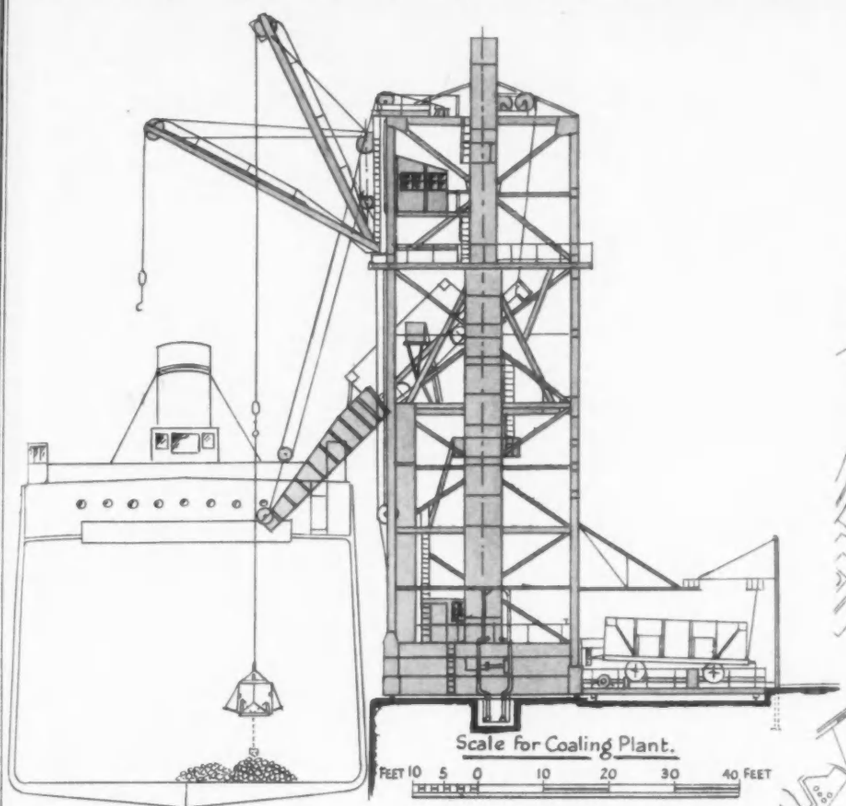
It could not be expected that in so comprehensive a purview, the programme of the Congress would include a very large proportion of topics of direct interest for port officials, and, except in so far as port undertakings require a wide range of plant and appliances, with a relation in some aspects to several of the papers, the subject of most importance to them was the River Clyde and the Harbour of Glasgow, described in a Paper by Mr. A. C. Gardner, the Engineer-in-Chief of the Clyde Navigation Trust. It is proposed to publish this paper in full in our next issue. The subjects of the other papers have been announced previously.

As regards the Exhibition itself, a word of commendation must be said for the enterprise and ability of its promoters. The preparation of the site at Bellahouston Park, covering an area of 175 acres and involving an outlay of no less than ten millions sterling, is an achievement of which the citizens of Glasgow may well be proud.

XUM

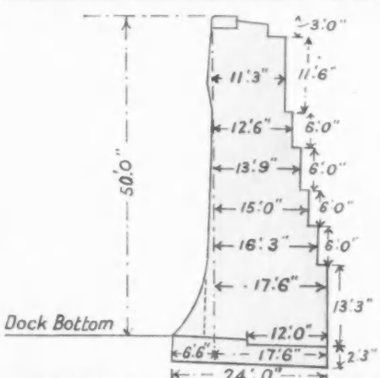
CARDIFF Ddocks.

CHIEF DOCKS MANAGER TO THE GREAT WESTERN RLY Co.;-W.J.THOMAS Esq.

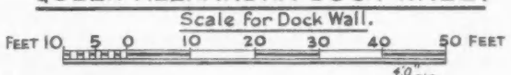


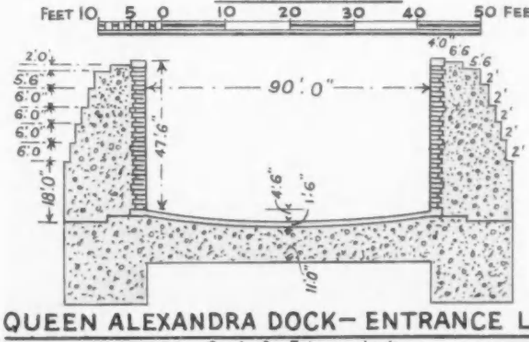
COAL HANDLING PLANT — QUEEN ALEXANDRA DOCK.

Supplied by the East Ferry Road Engineering Co Ltd

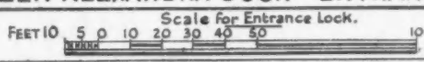


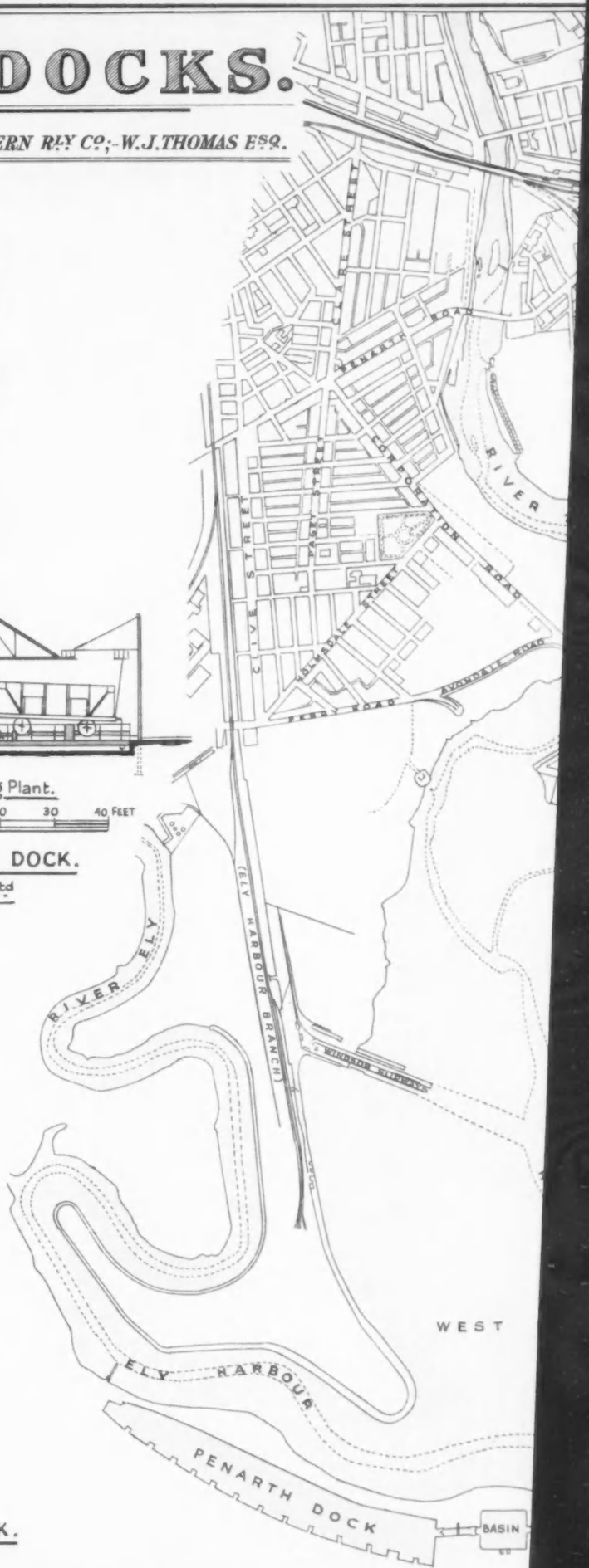
QUEEN ALEXANDRA DOCK WALL.





QUEEN ALEXANDRA DOCK— ENTRANCE LOCK.





WARD & FOXLOW

CK AND HARBOUR AUTHORITY, JULY. 1938.

FOXLOW, LITH., HARCOURT STREET, MARYLEBONE, W.

le For Plan.

The Bute Docks, Cardiff

The Great Coaling Port of South Wales

By W. J. THOMAS, Chief Docks Manager, Great Western Railway

Early History

BEFORE the construction of the first dock at Cardiff a busy coastal trade was carried on within the sea entrance of the Glamorganshire Canal, which was opened in the year 1798. The canal, which is twenty-five miles in length, was the first important achievement in connecting the vast mineral deposits of South Wales with the seaboard and developing the export of coal, which was conveyed by barges and shipped into vessels of about 200 tons burthen.

This canal is still in existence, and its waters are connected to the dock system by a junction lock, but there is nowadays no interchange of traffic via this water connection, and the canal does not form part of the dock undertaking, as its proprietorship is vested in the Glamorganshire Canal Company. There is still, however, a little traffic between the sea and the canal, consisting mainly of sand dredgers bringing in their cargoes from the Bristol Channel.

Belt Conveyor-type Coal Shipping Appliance

The steady development of the coal trade of South Wales and the improved means of railway transport in the nineteenth century was responsible for the rise of Cardiff to a port of world eminence. The actual development of the Docks commenced about a century ago when, in October, 1839, the first dock, i.e., Bute West Dock and Basin, was opened. This was followed by the East Dock and Basin, which was constructed in two portions, the former section being opened in 1855 and the latter in 1859. The approach from the sea to these docks is through a dredged channel, known to-day as the Entrance Channel.

The first section of what is known as the "Deep Water" docks is the Roath Basin, which was opened in 1874, with its sea entrance in the widened entrance channel. This basin is connected to the earlier docks by a junction lock at the South end of East Dock. The Roath Dock, which was constructed later and opened in 1887, is also connected to the Roath Basin by a junction lock. The latest and largest dock to be constructed is the Queen Alexandra Dock, which was opened in 1907, and is connected to the Roath Dock by a wide communication passage, linking the two docks to form an extensive water area. The sea entrance to the Queen Alexandra Dock is through a large lock directly facing the Bristol Channel.

Entrance Channel

This Channel was originally a narrow cut from the mouth of the River Taff to the entrance of the West Dock, but it has since been developed into a broad waterway serving the entrances to the West, East and Roath Docks, and also several large graving docks, which are described later. Near the entrance to the West Dock is situated a tidal steam packet harbour where there are two floating pontoons for the use of cross-channel passenger steamers operating between Cardiff and the Bristol Channel holiday resorts.

West Dock and Basin

The West Dock, as previously mentioned, is the oldest in the system. The sea entrance to the tidal basin is 45-ft. wide, with an average depth of water on the outer cill of 28-ft. on ordinary spring tides. The dock is long and narrow, the length being 4,000-ft. and the width 200-ft.; the water area is 19 acres. The normal depth of water at the South end of the dock is 19-ft., and at the North end 12-ft. The dock and basin together have a walled quayage of 8,950-ft. This dock still plays an important part in the shipping trade, and is frequented by numerous coastal craft of all descriptions, and also the deep-sea fishing fleet owned by Messrs. Neale and West, Ltd.

East Dock and Basin

Parallel to the West Dock is the East Dock, 300-ft. longer, but much wider and deeper. At the southern end 1,000-ft. in length, is 300-ft. in width, and the remaining 3,300-ft. is 500-ft. in width. The normal depth of water in the dock at the South end is 25-ft., and at the Northern end 19-ft. The water area is 44 acres. The tidal basin, which has a water area of 2½ acres, is 380-ft. in length by 250-ft., and the total walled quayage for the dock and basin is 9,480-ft. The dimensions of the Sea Lock are: length 220-ft., width 55-ft., with an average depth at high water on ordinary spring tides of 31-ft. Fairly large-sized vessels of about 4,500 gross tonnage are accommodated in the dock.

Roath Dock and Basin

The Roath Dock is 2,400-ft. in length, with a width of 600-ft., and a jetty constructed of stone, 800-ft. in length, runs down the centre of the dock from the North-East quay. The water area is 33 acres, and the normal depth of water 33-ft. The Basin is 1,000-ft. in length by 550-ft., and, although a tidal basin, the depth of water is not allowed to fall below 28-ft. The sea lock is 350-ft. by 80-ft., with an average depth of 35-ft. at high water on ordinary spring tides. The lock connecting the dock and basin has the same width, with similar average depths as the sea lock, but is 600-ft. in length. The water area of the Basin is 13 acres. The walled quayage for the dock and basin totals 9,885-ft. Large cargo liners are accommodated in both the dock and basin.

Queen Alexandra Dock

This is the largest dock in the port. Its length is 2,550-ft., and the width 800-ft.; the water area is 52 acres, with an average depth of 37-ft., the walled quayage being 9,315-ft. It is provided with an exceptionally large sea lock, which compares favourably with large locks at other ports, being 850-ft. long by 90-ft. wide, and capable of receiving the largest cargo liners and a number of the large passenger liners, several of which have visited the port. The average depth at high water on ordinary spring tides is 39-ft. The dock is connected to the Roath Dock by a communication passage, the water in both docks being maintained at the same level, thus forming an exceptionally spacious water area of 85 acres, enclosed by a quay wall over three miles in length.

Export Trade

(a) **Coal and Coke.**—About 5 to 6,000,000 tons of coal and coke are shipped as cargo and bunkers through these docks annually to all parts of the world.

A feature of the port is the provision of a separate quay at each dock for the shipment of coal. The quays are equipped with several types of modern coaling appliances which ensure a speedy despatch.

(b) **Exports other than Coal.**—Upwards of half-a-million tons of export traffic, apart from coal and coke, is dealt with. This traffic is composed of patent fuel, steel rails, iron, carriage and wagon work, cement, grain and flour, oil, and general merchandise of all descriptions.

Patent fuel is manufactured in the large works owned by Messrs. British Briquettes, Ltd., which is situated between the Roath and Queen Alexandra Docks. There is a wharf specially

The Bute Docks, Cardiff—continued

provided in each of those docks for the shipment of this traffic. Normally, over 400,000 tons of this commodity is exported annually.

General Imports

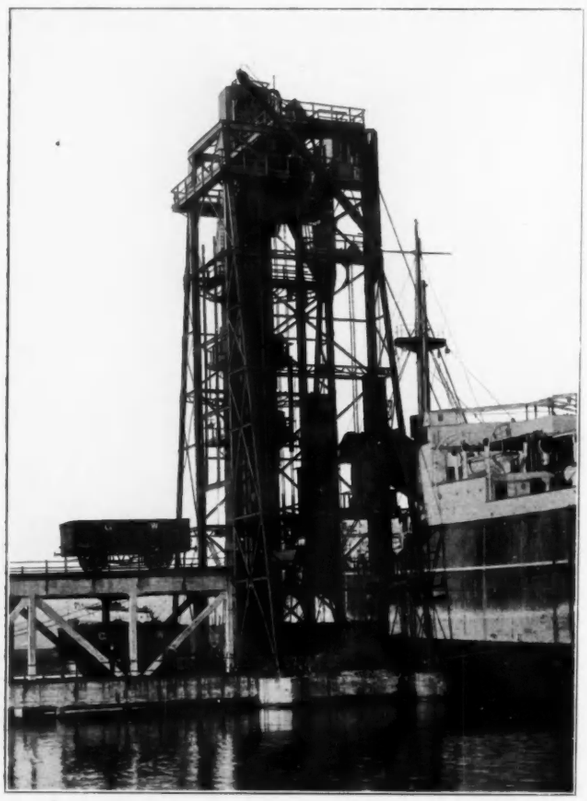
The general imports are normally in excess of 1,500,000 tons annually, and comprise iron ore, pig iron, blooms, billets, timber deals, pitwood, grain, flour and general merchandise, including potatoes, fruit, provisions and frozen and chilled meat, and also cattle.

Pitwood.—The importation and distribution of pitwood pit-props and mining timber from the White Sea, the Baltic, Norway, and Sweden, France, Finland, Newfoundland and Canada, forms one of the chief industries carried on in the port.

The wood is often discharged direct to truck, but in the busy season large stocks are retained at the docks, where there is spacious accommodation adjacent to the quays.

Timber.—In addition to the importation of wood for mining purposes, Cardiff is one of the chief ports in Great Britain for the handling of imported timber of all kinds, normally about 200,000 tons being dealt with annually. The timber is stored near the docks in the large timber yards of firms who have been engaged in the business for very many years, and a commodious shed at Queen Alexandra Dock is provided by the Railway Company for the storage of all classes of timber and plywood. Log timber is discharged overside into the dock, rafted, and taken to the large timber pond near the north-western boundary of the docks.

Grain.—Grain and flour imports average over 200,000 tons per annum, and large silos granaries and warehouses are available for storage purposes. The firm whose imports comprise the bulk of the annual grain traffic is Messrs. Spillers, Ltd., who have constructed at the North end of the Roath Dock large modern mills and silos. The manufactured flour and other products are distributed to all parts of the country by rail and road as well as by coasting craft. The grain is discharged from vessels lying at the jetty by means of pneumatic movable elevators, and conveyed on covered belts to the silos.

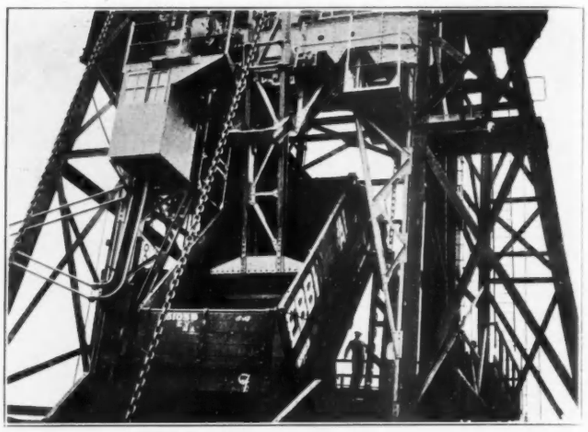


A Typical Coal Hoist at a South Wales Dock

Iron and Steel.—Situated at the docks is one of the finest steelworks in the country, the "Dowlais Works," owned by Messrs. Guest, Keen, Baldwins Iron and Steel Co., Ltd., covering an area of about 116 acres. It is in connection with this industry that the huge annual imports of iron ore are required. The imported ore, which is received chiefly from Spain, North Africa and Sweden, is discharged at the North-West Quay of Roath Dock. Three blast furnaces are maintained continuously for the production of pig iron, etc., which is distributed inland, together with the manufactured products of ancillary businesses. Iron and steel is also exported at the wharf.

Fish.—About 8,000 tons of fish is landed each year in the West Dock by the steam trawlers of Messrs. Neale and West, Ltd. In connection with this traffic, an ice factory, owned by the Cardiff Pure Ice Company, has been constructed on the Fish Wharf. Messrs. Neale and West have also erected a fish manure factory in the near vicinity of the docks.

Sand.—The importation of sand, chiefly in connection with the building trade, is another active business at Cardiff. Wharves are specially reserved for this traffic, and as much as 70,000 tons have been imported in one year.



Mechanical Spade or "Digger" for removing washed duff coal from wagons

Oil.—Last year 20,000 tons of oil were dealt with, and this traffic is steadily increasing. Messrs. Industrial Traders, Ltd. have an oil storage plant at the South side of Queen Alexandra Dock, from which vessels can bunker. The Mountstuart Dry Dock Company have also provided an oil-bunkering plant at their dry docks. Messrs. Bird and Son have a pipe line from their creosote works to a wharf on the North side of Roath Dock for the exportation of creosote oil.

General Cargo.—Cardiff also possesses a valuable and extensive general cargo trade, importing over 200,000 tons annually. Excellent quayside cranes, and commodious warehouses are provided, enabling traffic to be discharged or shipped direct to or from rail or through these warehouses. Several Continental, American and Canadian lines operate regularly from the port, also frequent visits are made of large cargo liners in the Australian and New Zealand trade bringing frozen meat and general produce. The port offers special advantages for the importation of fruit and many cargoes of oranges, apples, lemons, onions, grape-fruit, etc., in season from Spain, Egypt, Italy, California, Canada, Australia, and New Zealand, are received, warehoused, and distributed to all parts of the country.

Coastwise Traffic.—An extensive coastwise trade passes through the port. This class of trade is handled chiefly in the West and East Docks, where Coast Lines, Ltd., and other firms, have large warehouses. Regular services are maintained by modern coasting craft to all parts of the British Isles.

One of the important branches of this trade, although not wholly coastwise, is the Potato traffic, for which Cardiff is one of the chief ports in Great Britain. Cargoes are received all the year round from the Channel Islands, Northern Ireland, Scotland, with further large importations from the Mediterranean ports. Grain and flour are forwarded from Messrs. Spillers' Mills in small coasting craft to places in the Bristol Channel and South of England. Numerous craft carry coal for coastwise destinations.

Importation of Live Cattle.—Cardiff is one of the few ports in Great Britain which is licensed by the Board of Agriculture and Fisheries for the importation of live cattle.

Special facilities are provided for this important branch of the import trade, and the advantages offered have attracted, during the past few years, many consignments of live cattle from Canada, South Africa and Ireland.

The cattle lairs are situated at the north-west end of Roath Basin, and have recently been extended to accommodate 7 to 800 head of cattle. Vessels berth alongside the lairs where the cattle are discharged. The lairs are equipped with every facility for the watering, feeding and inspection of the cattle. Contiguous to the lairs are the abattoirs. There are also large chill rooms connected with the abattoirs by means of overhead runways to effect the transport of carcases between these points. An extension of these runways to the direct loading platform gives a similar advantage when the carcases are despatched by rail.

Cattle can be loaded direct from the lairs into rail vehicles and conveyed rapidly to any destination.

The Bute Docks, Cardiff

Discharging a Cargo of Canadian Pine

Interior View of a Transit Shed

The Bute Docks, Cardiff—continued

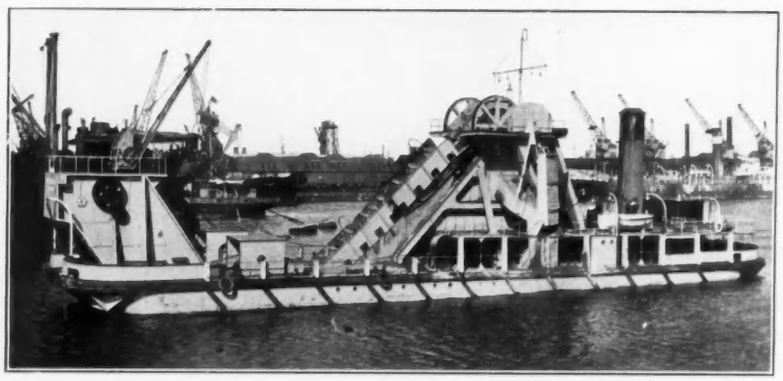
An auction ring equipped with a dial weighing machine is provided for the use of salesmen, auctioneers and buyers, making it possible for the cattle to be landed, sold and delivered to the purchaser within a few hours.

Trade Returns.—The following figures relate to the trade of the port during a recent year, and show the variety and extent of the business transacted.

IMPORTS	Tons
Iron Ore	656,350
Copper and other Ores	3,072
Iron and Steel	83,784
Timber and Deals	160,495
Pitwood and Mining Timber	473,604
Grain and Flour	221,780
Oil	3,731
General Merchandise	289,509
Building Sand	36,211
Ballast	252
Total	1,928,788

EXPORTS	Tons
Coal and Coke	7,211,609
Patent Fuel	350,217
Iron and Steel	69,342
Tinplates	19,061
Cement	21,495
Grain and Flour	39,485
Oil	2,498
General Merchandise	50,069
Ballast	2,073
Total	7,765,849

No. of Vessels arrived	5,188
Total Net Register Tonnage of Vessels arrived	4,104,486



Dredger operating at South Wales Docks

Passenger Traffic.—Cardiff has on numerous occasions been visited by large passenger liners. Excellent arrangements have been made at the Queen Alexandra Dock for the landing and embarkation of passengers as well as for the berthing of the liners. For the convenience of passengers, main line through trains run right to the dock side. Two of the largest liners to visit Cardiff in recent years are the s.s. "George Washington," gross tonnage 23,788, belonging to the United States Line, and the White Star liner "Baltic," gross tonnage 23,884.

Other Industries.—There are many smaller industries carried on at the docks, particularly in the various branches of the engineering trades.

PORT FACILITIES

As the export of coal forms such a large part of the business of the port, the Great Western Railway Company has always taken advantage of improvements in coal-loading appliances, and the equipment at Cardiff is of the most modern type. On the straight quay at the North side of Queen Alexandra Dock are nine hydraulic movable hoists served by electric traversers, which carry wagons to and from the feed roads, and each of these hoists is capable of handling 20-ton wagons. At the Roath Dock and Basin are three different types of appliances; on the South side of the dock are four hydraulic coaling cranes and two electric belt conveyors. Each crane is equipped with a large box fitted with doors in the bottom, which can be lowered into a pit in the quay, where the contents of a wagon are tipped into the box for lifting on board the vessel. The doors in the bottom of the box are not opened until the box is lowered into a vessel's hold, and in this way the breakage of coal is reduced to a minimum.

The electric belt conveyors are the most recent coal shipping appliances to be installed at Cardiff. Coal is tipped from wagons on to an endless belt which projects over a vessel's hold, from which coal passes into an escalator type of anti-breakage appliance, and is lowered to the bottom of the hold. When there is sufficient coal in the hold the anti-breakage escalator is removed, and the coal then passes direct from the belt into the hold. On the South side of Roath Basin, two modern fixed hydraulic hoists, capable of handling 20-ton wagons, are installed. The West side of East Dock is also equipped for the loading of coal, and seven fixed high-level hydraulic hoists, each able to handle 20-ton wagons, are in use. At the East side of West Dock are four coal tips, used for loading and bunkering coasting and fishing vessels.

Every effort is made to reduce the breakage of coal during loading operations, and eight escalator-type anti-breakage appliances, as described above, are provided for use at the various appliances. In addition, twelve anti-breakage boxes are available. In order to speed up the shipping of duff from wagons, from which the material does not run easily, mechanical diggers have been installed at East Dock, Roath Basin and Queen Alexandra Dock.

Altogether, there are 28 coal-loading appliances at Cardiff, and of these 20 are able to handle 20-ton wagons.

In connection with the coal export trade, large areas in the vicinity of the docks have been laid out with standage sidings, where wagons can be brought from collieries and stationed pending shipment operations. As these storage yards are in close proximity to the coal-loading quays, coal can be worked very quickly on to the tip roads as and when required for shipment.

The General Cargo trade forms a very important part of the business of the port, and in addition to coal-handling facilities each dock fitted for the loading and discharging of all kinds of general cargo. On the North quay of Queen Alexandra Dock there are large warehouses and cold stores into which vessels can discharge direct. All kinds of general cargo, including large quantities of foodstuffs and fruit, are discharged into these warehouses, and deliveries are promptly effected by rail and road.

Moreover, a large quayside area at the North side of Queen Alexandra Dock is set aside specially for the storage of timber and pit-props, which are discharged at this point as well as a quay with an overhead gantry from which patent fuel is loaded into vessels. An overhead rail track connects the gantry with the adjacent fuel works of British Briquettes, Ltd.

The quayside appliances for the handling of the various commodities which are dealt with at the North side of the Queen's Dock, consist of 21 electric and 13 hydraulic cranes, including one electric crane able to lift up to 15 tons.

The Roath Dock is similarly equipped for the handling of general cargo, and on the North quay are warehouses and 22 hydraulic and 4 electric cranes. Similar commodities to those handled at Queen's Dock are dealt with at Roath Dock, with, in addition, considerable quantities of iron ore, discharged for the huge steel works of Messrs. Guest, Keen, Baldwins Iron and Steel Co., Ltd., which are located to the North of Roath Dock. Large quantities of grain are also dealt with at Roath Dock. Within recent years, Messrs. Spillers, Ltd., have erected mills at the East end of the dock, and steamers berth alongside a jetty which is adjacent to the mills, and cargoes are discharged by suction plant, which can travel along the jetty.

East Dock is also equipped for handling general cargo, and the extensive business carried on by Coast Lines, Ltd., is conducted from this dock. Part of the quay on the East side of the Dock is set aside for the discharge of all classes of timber, and while in certain cases ship's gear is used for this work, there are altogether 20 hydraulic cranes which are used for discharging work.

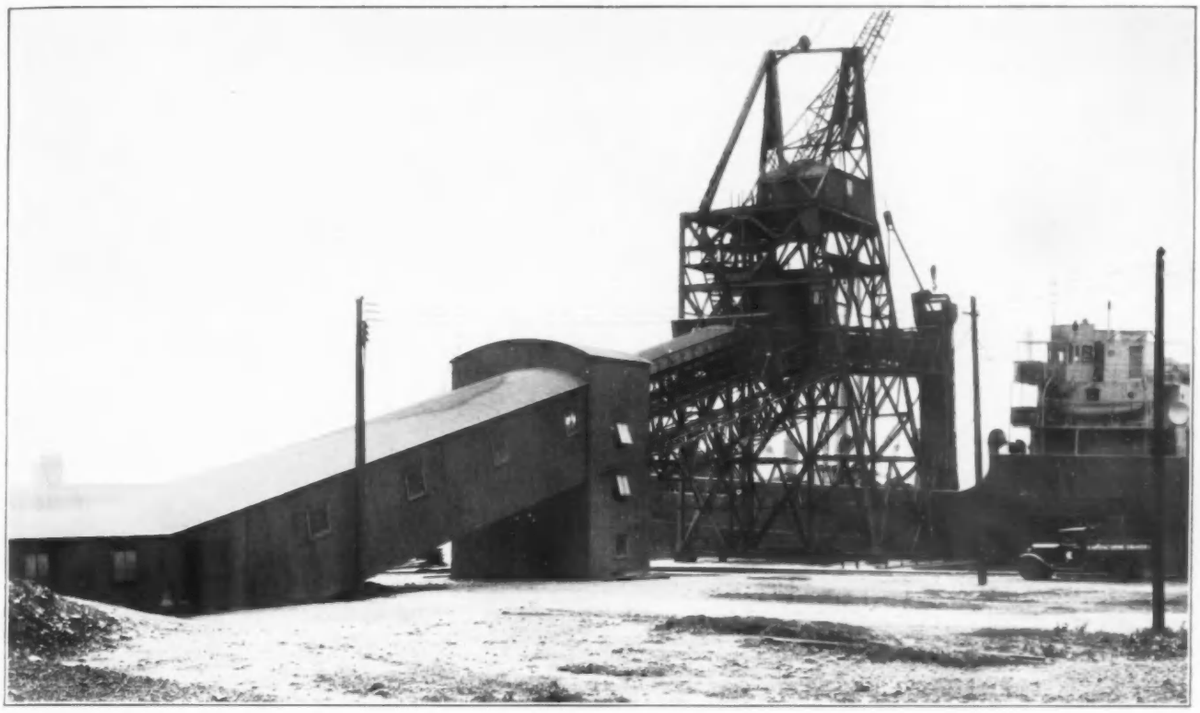
Regular coasting services are maintained from East Basin by Messrs. Sloan's steamers and from West Dock by Messrs. Gilchrist's vessels.

The extensive warehouses at all the docks are built on the quay side, and are equipped with modern electric trucks, conveyors, etc., for the prompt handling of goods stored in the premises. At East Dock there is a bonded warehouse, and the total warehouse space available at the port exceeds 822,000 sq. ft.

The Great Western Railway Company undertakes all classes of loading and discharging work, there being ample labour available. There are other stevedoring firms who carry out similar work at Cardiff, but the majority of the labour requirements of the port are provided by the Great Western Company. In addition to the equipment previously mentioned, the Company has a floating crane, able to lift up to 125 tons, and this crane is available for use at any of the South Wales ports, on previous notice having been given.

The hydraulic power required to operate the various loading and discharging appliances, as well as the lock gates and swing-bridges, is generated at three power houses, at Queen Alexandra, Roath and East Docks respectively.

The Bute Docks, Cardiff—continued



Belt Conveyor Coal-Shipping Appliance

So as to facilitate the movement of vessels in the docks, the Great Western Company has two modern powerful tug-boats, which are available at all times, while towage outside the docks is carried out by a fleet of privately-owned tugs.

A considerable amount of ship repair work is carried on at the docks, and eight dry-docks, together with a floating pontoon and a gridiron are able to accommodate the largest type of vessel using the port. Seven of the dry-docks and the floating pontoon are owned by private companies, and well-equipped engineering shops situated adjacent to the dry-docks, expedite the carrying out of repairs. The Gridiron and the Commercial Dry Dock are owned by the Dock Company, and are available for the use of any firm. The Commercial Dry Dock is entered from Roath Basin, and is 600-ft. long, with an entrance of 60-ft., and a travelling electric crane to lift up to 15 tons has recently been installed.

Pilotage.—Pilotage to the port is not compulsory, but the majority of vessels using the port engage the services of a licensed pilot. An efficient service by means of steam pilot cutters is maintained by the Cardiff Pilotage Authority.

Book Reviews

Reinforced Concrete Piling, by F. E. Wentworth-Sheilds and W. S. Gray. Pp. viii + 126. Price: 8s. 6d. London: Concrete Publications, Ltd.

In their introduction to the subject in Chapter I, the authors point out the steadily increasing use of reinforced concrete piles and the advantages these offer over timber piles. Proceeding, they describe the materials required, the shape of the cross-section, the disposition of the reinforcement and the various kinds of shoe. Chapter II is devoted to the design of piles, distinguishing bearing piles and sheet piles, the calculations for strength of the former being based on the researches of Mr. Hiley, whose formula is approved and adopted; stresses in lifting are also considered. Succeeding chapters deal with groups of bearing piles, sheeting piles, anchorages and retaining walls, jetties and fenders, piling in sea-water, specification for piles and measurement, construction methods, cast-in-situ piles and descriptions of piling works. There are seven appendices and a like number of tables. The book is abundantly illustrated by diagrams and photographs. It has a serviceable index and is well produced.

Among the number of existing books and publications on the subject of concrete piles, the present manual will take a prominent place as a convenient and concise account of the essential information required for this form of construction. It should be of undoubted value to those engineers who are engaged on maritime works, since it is clearly based on a large amount of practical experience, in confirmation of which it is only necessary to point out that the senior author was for a number of years Docks Engineer of the Southern Railway and responsible for the important development works at the Port of Southampton. Some interesting particulars are given of the pile-yard at Southampton Docks for the construction of piles, 15-in. square, and ranging from 47 to 55-ft. in length. These were for shed foundations. Rather larger piles, 16-in. square and up to 66-ft. in length, were made for the dolphins to which the floating dock is moored. The construction of piles of the same scantling, with lengths up to 45-ft., as used at the Manchester Ship Canal sheds, is also described.

Seaports and Hinterlands, by A. J. Sargent. Pp. x + 188. Price 8s. 6d. net. London: A. and C. Black.

Professor Sargent has made a selection of typical seaports in Europe and North and South America for the purpose of investigating the geographical sources and destinations of the commodities which pass through them in the way of imports and exports. In other words, he has compiled, in each case, a survey of what is commonly called, for want of a better term, the hinterland. It is an elusive term, difficult of exact interpretation and involving the consideration of quite a number of factors. Besides physical geography, economics and politics, even history and climate have each a bearing on the determination of the bounds of a hinterland. The transport of goods between various localities and the choice of the gateway by which the goods are dispatched overseas depends, indeed, in the last resort on the individual decision of the sender, who may be influenced by a variety of inducements, some even of a private and imponderable nature. Professor Sargent's conclusion is that " the pure hinterland appears as characteristic of regions of fairly simple internal economic structure and strong geographical controls. As the organisation becomes more complicated, economics and commercial factors tend to obscure the ultimate geographical basis of the traffic, and the definition of the hinterland becomes more and more a matter of statistics."

The ports selected for review are Hamburg, Rotterdam, Antwerp, New York, Philadelphia, Baltimore, Montreal and the St. Lawrence, New Orleans and the Mississippi Basin, together with a general survey of the conditions in Argentina and Uruguay, Brazil and the North and West Coasts of South America. There are ten maps and diagrams and a good deal of useful commercial and statistical information, with serviceable comments on its application to the writer's investigation.

Professor Sargent's discrimination in the use of the terms harbour and port is timely and apposite. It would be well if the distinction were more generally recognised. A harbour is essentially a place of shelter and accommodation for shipping. It only becomes a port by virtue of the trade which passes through it, requiring the provision of quays, sheds, warehouses and the multiplicity of appliances for handling and storing goods.

Southampton Docks Extension*

By MALCOLM GORDON JOHN McHAFFIE, M.Inst.C.E.

THE works described in this Paper are those recently carried out by the Southern Railway Company at Southampton in what was formerly known as the West bay of the River Test, extending from the Royal Pier to Millbrook Point. Upon reference to Fig. 1, it will be seen that the Eastern and Western estates are separated by waterside property belonging to the Southampton Harbour Board, who also own and manage the Town Quay and the Royal Pier. There is, however, rail and vehicular road connection between the two estates, and all rail sidings are connected to the Southern Railway system.

In the original lay-out, consideration was given to two schemes for the berthing of ships, the first alongside a straight quay-wall running from end to end of the site, and the second alongside five large jetties projecting out into the River Test in a north to south direction. The advantages of the first appeared to be outweighed by those of the second, and it was decided to adopt the latter. Upon the recommendation of the late Sir Frederick Palmer, K.C.M.G., C.I.E., Past-President Inst. C.E., this decision was reversed, and the straight quay as shown in Fig. 1, was adopted. The position of the quay has been arranged so as to permit the future provision of a jetty about 4,500-ft. long by 400-ft. wide, 600-ft. away from, and parallel with, the quay-wall. Space has been reserved at the western end of the new estate for the future provision of another graving dock alongside that already built.

The reclaimed land has a frontage to the River Test of about 2 miles, and a depth of about ⅓ mile; the area is 407 acres, of which roughly one-quarter belongs to the Southampton Corporation.

The works will be described under the following headings:—

- Works between the Town Quay and the Royal Pier.
- Dredging and reclamation.
- Quay-wall.
- King George V graving dock.
- Condensing-water culverts for the Corporation electricity station, and storm-water drainage.
- Subsidiary works, comprising:—
  - Passenger and cargo sheds.
  - Carriage-cleaning and warming shed.
  - Railway sidings.
  - Vehicular roads.

Throughout the Paper and in the illustrations, the levels given refer to dock datum, which is 100-ft. below dock standard cope, and 87.75-ft. below ordnance datum (Liverpool). The tidal range is 13-ft., H.W.O.S.T. being at a level of 94.00 and L.W.O.S.T. at a level of 81.00.

Works Between the Town Quay and the Royal Pier

To provide rail connection between the Eastern and Western estates, the previously existing arrangement of

Fig. 1
Plan of Docks Extension and Eastern Dock Estate

* Paper read before the Institution of Civil Engineers on 26th April, 1938.—Reproduced by permission of the Council of the Institution.

Southampton Docks Extension—continued

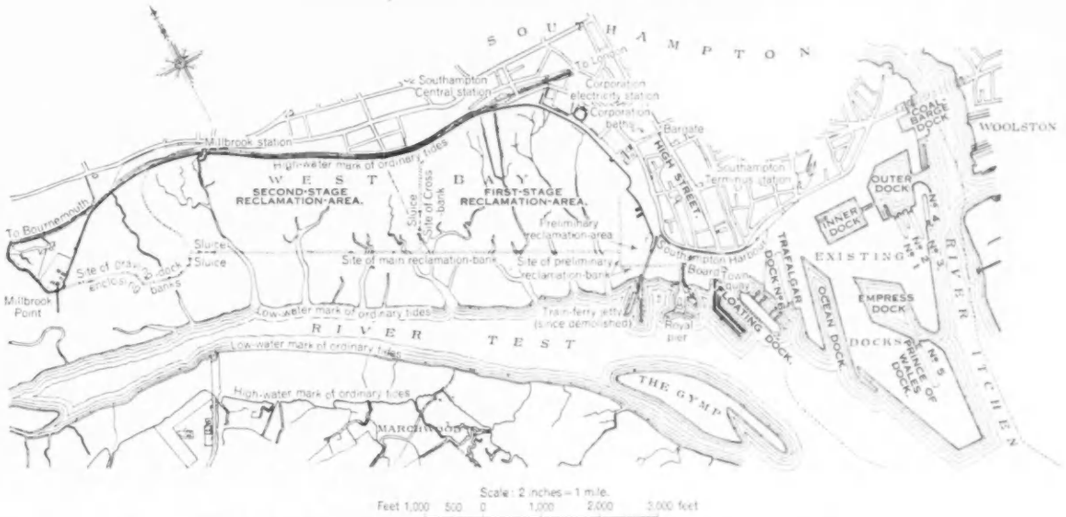


Fig 3. Site of Docks Extension before Works were commenced

sidings in the vicinity of the Town Quay and Royal Pier had to be remodelled, and, in order to obtain adequate space for this to be done, it was necessary to reclaim a strip of land between the Town Quay and Royal Pier. Accordingly, a new retaining wall, 420-ft. long, was built about 100-ft. in front of an existing quay-wall and the intervening space was filled up with dredged material. The rail connection also involved the demolition of the former toll-house at the entrance to the Royal Pier and the building of another in substitution.

The new retaining wall is shown by cross section in Fig. 2. It consists of T-shaped reinforced concrete "Ravier" piles, anchored back by hinged reinforced concrete ties.

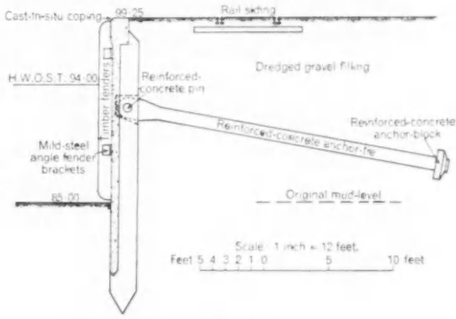


Fig. 2
Quay-wall between Town Quay and Royal Pier

Dredging and Reclamation

The formation of the approach channel and the two swinging-areas (one opposite each end of the quay-wall) involved deepening the bed and the mud-flats on the left bank of the River Test from an average of about 7-ft. to a depth of 35-ft. below L.W.O.S.T. The dredging was done by bucket-ladder dredgers. The total quantity removed was 16,450,000 cu. yds., measured *in situ*, of which 6,680,000 consisted of soft mud and peat, 3,500,000 of gravel and 6,270,000 of sandy clay. The soft mud and peat were taken to sea in hopper-barges and dumped; the gravel was used for the reclamation banks and for concrete aggregate; and the sandy clay was taken in solid-bottom barges alongside stationary pumping vessels and pumped ashore through 24-in. diameter pipe-lines for reclamation.

The reclamation was carried out in two stages, divided by a cross bank built at right angles to the quay-wall, and situated approximately midway along the length of the area to be reclaimed, as shown in Fig. 3. The first and second stages of reclamation were eastwards and westwards of the cross bank respectively.

Preliminary Reclamation Works

Upon reference to Fig. 3 it will be seen that landward of the former high-water mark of ordinary tides, practically no dry ground was available for use as contractors' yards; the first requirement, therefore, was to reclaim a preliminary area, roughly triangular in shape and about 18 acres in extent, at the eastern end of the bay. The southern embankment for this area (now forming the seaward side of land belonging to the Corporation, which they propose to lay out as a recreation ground) commenced at the Royal Pier and proceeded westwards for a distance of 1,000-ft., and thence northwards to the old foreshore. In addition to providing space for contractors' yards, the reclamation of this area was intended to test the practicability of constructing the enclosing banks with gravel obtained from the dredging operations.

A typical section of the bank westwards of the Royal Pier is shown in Fig. 4 (a). Along the line of the bank the mud was dredged away in the form of a channel with a bottom width of about 15-ft., exposing the underlying gravel stratum. Firm dredged material was then deposited by small hopper-barges to a height of about 4½-ft. above L.W.O.S.T. Construction above this level was carried on by means of a vessel consisting of two pontoons spaced 23-ft. 7-in. apart, the space being bridged by an overhead steel structure carrying a bucket-

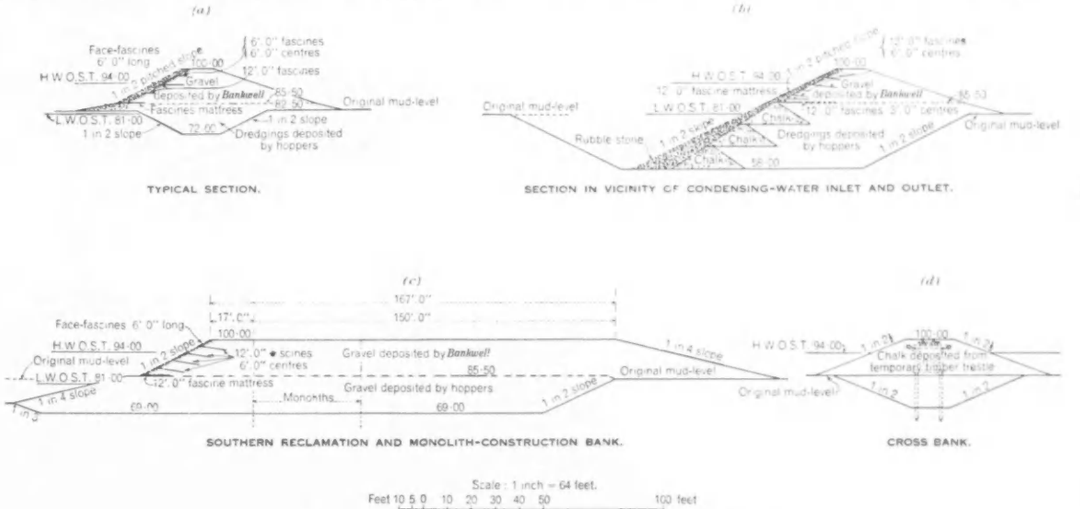


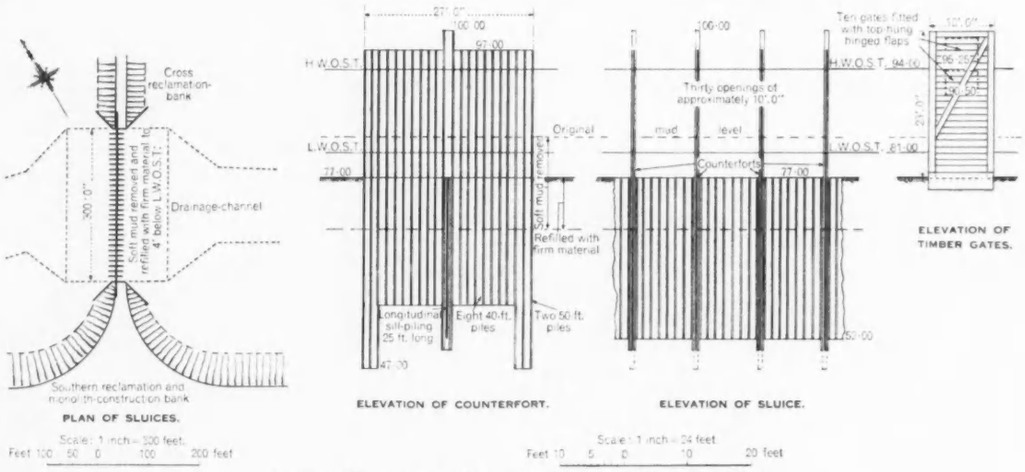
Fig. 4. Reclamation-Banks westward of Royal Pier

Southampton Docks Extension—continued

ladder elevator and a projecting arm equipped with a travelling rubber belt. Barges containing dredged gravel were towed into the space between the two pontoons, and were unloaded by the bucket-ladder elevator into an overhead hopper through which the gravel passed to the travelling belt, whence it was deposited in the bank. Frequently the output from the vessel, named the "Bankwell," was over 3,000 cu. yds. (barge measurement) per day of 24 hours.

its western end, was dredged behind the main bank; the western end of this channel is shown in Fig. 5. A similar drainage channel was provided in the second-stage reclamation area.

Along the line of the cross bank a channel was dredged, as previously described, into which firm dredged spoil was dumped from hopper barges. A temporary timber trestle was then constructed, from which chalk was cast out from railway wagons. A section of this bank is shown in Fig. 4 (d).



Figs. 5. Temporary Sluices in Cross Reclamation-Bank

The seaward side of the bank was temporarily protected by brushwood fascines. This protection was commenced with a fascine mattress 12-ft. wide along the toe at a level of 85.50, and above this level the face-fascines were tied into the bank by single fascines placed 3-ft. apart vertically and 6-ft. apart horizontally; all the fascines were well pegged down into the gravel with forest pickets. In the vicinity of the site of the intake and outlet of the condensing-water culverts it was necessary for the foundation of the bank to be taken down to a level of 58.00; the section of the bank in that vicinity is shown in Fig. 4 (b). Subsequently the seaward face of the bank, being permanent work, was pitched with rubble stone.

First and Second Stage Reclamation Works

The method of bank building described above having proved efficient and economical, an adaptation of it was adopted for the main reclamation bank, through which the monoliths forming the new quay-wall had to be sunk; it was made 167-ft. wide on top to accommodate the contractors' crane-trucks and works railways, and is shown in cross section in Fig. 4 (c). After the monoliths had been sunk that portion of the main bank in front of them was dredged away.

It was found by a model that the velocity of water, whilst the first-stage reclamation area was still tidal, might scour away the back of the main bank during the fast ebb of a spring tide, and to meet this contingency a drainage channel, about 6-ft. deep and widening from 50-ft. at its eastern end to 150-ft. at

Temporary Sluices

The construction of the main bank preceded that of the cross bank, so that, until closed by the latter, the area of the first stage of reclamation was tidal. It was realised that a critical point would be reached when the velocity of the current through the gradually decreasing gap between the two would be sufficient to scour away the end of the cross bank and the back of the main bank opposite to it. In order that the banks should not be eroded it was considered that the velocity of tidal flow should not exceed three miles per hour; calculations showed that a gap 300-ft. long would suffice to keep the flow within that limit at any state of the tide, and it was therefore decided to construct the temporary sluices shown in Fig. 5.

Along the length to be occupied by the sluices, and for a width of 100-ft., the soft mud was dredged away, and clay was dumped from hopper-barges thereon to a level of about from 78.00 to 80.00; this was subsequently levelled off to 77.00 by re-dredging.

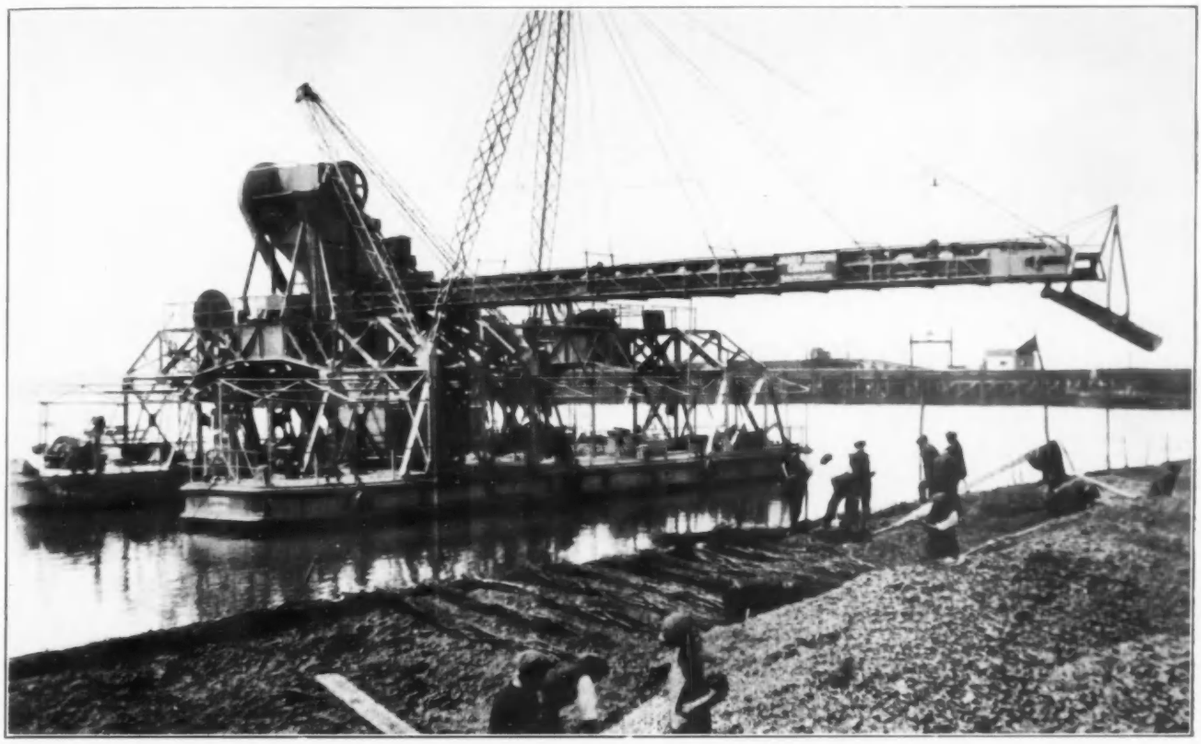
A sill of steel sheet-piling in 25-ft. lengths was then driven along the centre-line of the sluices, the top being left at a level of 77.00. At right angles to the sill twenty-nine counterforts composed of 40-ft. and 50-ft. steel sheet-piles were driven at intervals of 10-ft., the tops finishing at a level of 97.00; the junctions between the counterforts and the sill were effected by special cruciform piles 50-ft. long. Wing-walls of steel sheet-piling were driven at each end of the sill, and were connected to it by special junction piles; the wing-walls were anchored back into the banks at either end of the sluice.

General View of Quay, Southampton Docks

Framed timber gates were constructed to slide into the recesses of the cruciform piles, each one being specially fitted to its sill. Ten of the gates were provided with two openings 5-ft. wide by 3-ft. 9-in. high, the sill of the lower openings being at a level of 90.50 (that is, at the level of high water neap tides), and that of the upper openings being at 95.25; the openings were fitted with top-hung hinged flaps, arranged to open outwards, thus permitting a discharge of water from the area to be reclaimed without permitting ingress of water to the area during high tides. After being fitted one by one in their respective positions the timber gates were stored on the adjoining banks, and when everything was in readiness they were all dropped into place during one period of low water neap tide. Chalk was then deposited on either side of them up to the level of high water neap tide as quickly as possible in order to strengthen the whole structure.

Although the dropping of the sluice doors into place was expected to be carried out according to programme (as indeed it was) there was a possibility that the chalk would not be deposited on either side before

Southampton Docks Extension—continued



The "Bankwell" and Temporary Fascine Protection to Reclamation Banks

the following spring tides. In view of this possibility, two extreme cases of pressure on the gates required consideration, namely:—

(1) With the level of impounded water inside at about 6-in. above the sill of the lower openings (that is, at a level of 91.00), with water at L.W.O.S.T. on the outside.

(2) With the level of impounded water inside at 90.50 with water at Extraordinary H.W.S.T. (that is, at a level of 96.00) on the outside.

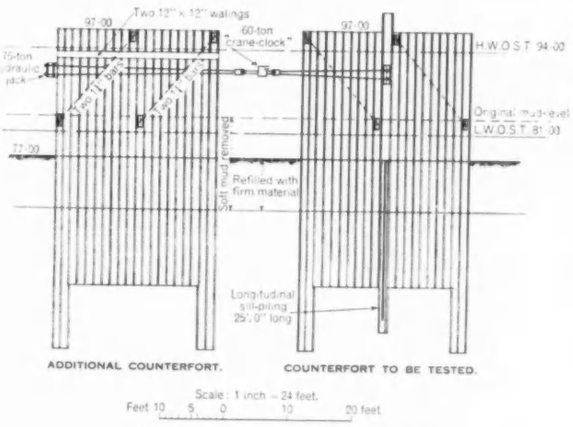


Fig. 6. Testing of Counterforts

In each case the lateral pressure to be resisted amounted to about 26 tons, the resultant in case (1) being at a level of 82.00, and that in case (2) being at 85.20.

As no data regarding the strength of steel sheet-piling in a longitudinal direction appeared to be available, and as it was a practicable impossibility to calculate with any degree of accuracy the behaviour of the counterforts under load, it was decided to ascertain this, as far as possible, by test.

Tests on Counterforts

It was considered that the counterforts might fail either by sliding, overturning, or buckling. The test was therefore designed so that:—

(a) a lateral pull greater than 26 tons could be applied in order to test resistance against sliding;

(b) a moment could be applied greater than that which might be produced in either case (1) or case (2) above, in order to test the resistance against overturning, the test load being applied at a level of 90.50;

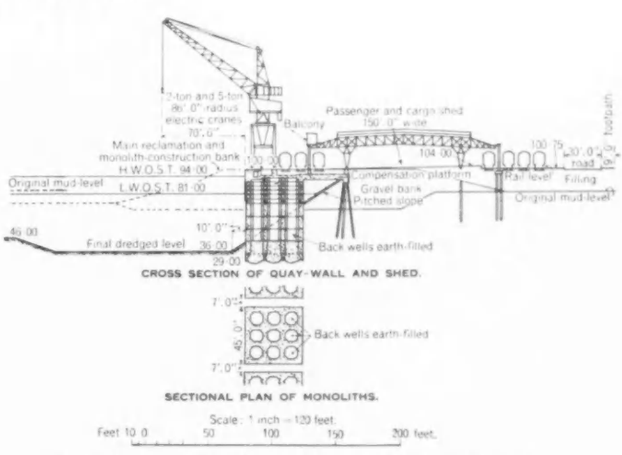
(c) observations could be made for any sign of failure of the counterfort by buckling or otherwise.

An additional counterfort was accordingly driven in line with that to be tested, a gap of about 12-ft. being left between them, as shown in Fig. 6. The function of the additional counterfort was solely to serve as an anchorage from which a pull could be exerted on the counterfort to be tested.

As there was about ¼-in. play in the clutches, it was thought that excessive deflexion, or possibly failure, might arise through the piles sliding in the clutches when the load was applied. To resist this shearing effect it was considered that diagonal ties might be necessary; in designing these ties it was assumed that all piles were pin-jointed at ground-level, and that half the shear only would be taken up by the friction of the piles in the clutches; upon these assumptions it was found that 1¼-in. bars might be necessary. In the additional counterfort the ties, together with the 12-in. by 12-in. walings, were tightened up, but in the counterfort to be tested the ties were left slack, as it was thought the test might show them to be unnecessary; actually, this proved to be the case.

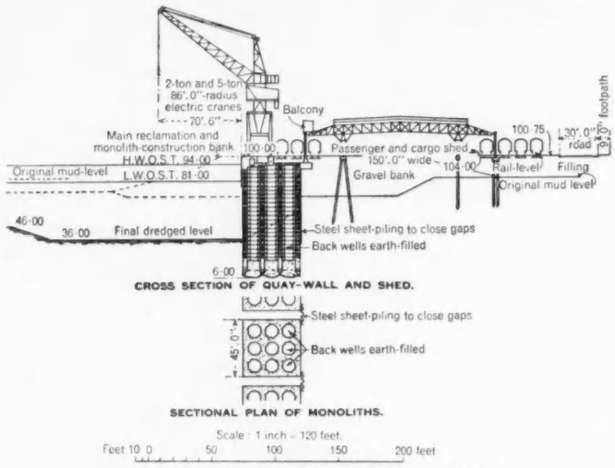
The pull was effected by means of a 75-ton hydraulic jack at one end of the additional counterfort, and was transmitted to the counterfort to be tested by four 1½-in. steel bars, a 60-ton "crane-clock" being placed between the two counterforts to register the increments of load.

The test proceeded until a load of 45 tons was registered, when the flange of the pile against which the hydraulic jack was resting buckled.



Figs. 7. Monolith Quay-Wall as originally designed

Southampton Docks Extension—continued



Figs. 8. Monolith Quay-Wall as modified

The loads equivalent to case (1) and case (2) compared with the test-load as follows:—

	Force	Moment
Case (1).—Tide-level at L.W.O.S.T. ...	25·7 tons.	231·3 tons-feet.
Case (2).— ,, ,, ,, E.H.W.S.T. ...	25·3 ,,	311·5 ,, ,,
Maximum test-load applied	45·0 ,,	787·5 ,, ,,

A permanent horizonal deflexion of 1.4-in. was observed in the counterfort under test. Neither of the counterforts showed signs of buckling under the load.

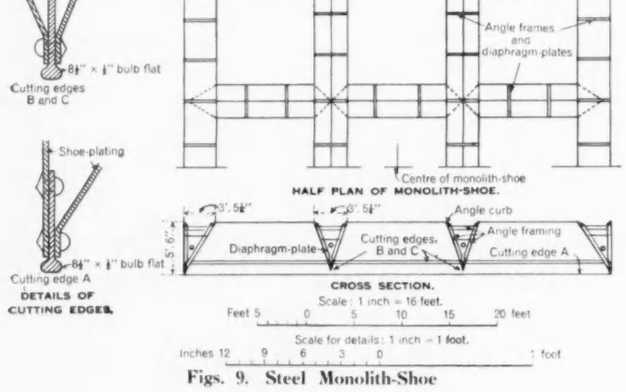
Quay-Wall—Construction

The quay-wall has a total length of 7,542-ft., and is shown in cross section in Figs. 7 and 8. For 7,050-ft. of its length it has been designed for a depth of water of 45-ft. alongside at L.W.O.S.T. It consists of one hundred and forty-six monoliths, each 45-ft. square in plan, and having nine octagonal-shaped wells measuring 10-ft. 4-in. across the flats. The outside and cross walls were 3-ft. 6-in. thick. The first seventy-eight monoliths at the eastern end, comprising the first stage of the work, were spaced 4-ft. apart, and the remaining sixty-eight, comprising the second stage, were spaced 7-ft. apart. The shoes, which are shown in Fig. 9, weighed about 34 tons each; they were 5-ft. 6-in. high and consisted of steel plates riveted to angles. To strengthen the cutting edge an 8-in. by ½-in. bulb plate was introduced between the outside and cant-plates.

The shoes were delivered to the site in sections, and were erected on the gravel embankment previously described, where the site-riveting was performed. The bases of the monoliths were formed in reinforced concrete, in and above the shoes, to a total height of 15-ft. 6-in. above the cutting edges; above the bases construction was continued in concrete blockwork, rising three courses to 10-ft.

When the reinforced-concrete bases had been formed, they were sunk by means of grabs operating in the wells until their tops were level with the surface of the embankment; three courses of blockwork were then built and sinking operations were renewed. Building and sinking in lifts of 10-ft. were thus continued until the monoliths had reached the desired depth. As the result of experience in the first-stage monoliths it was considered advantageous to substitute in-situ concrete for the lower twelve courses of blockwork, and this procedure was adopted in the second stage of the work.

Grooves were provided in the tops of all blockwork courses throughout the outside and cross walls for the reception of 1-in.



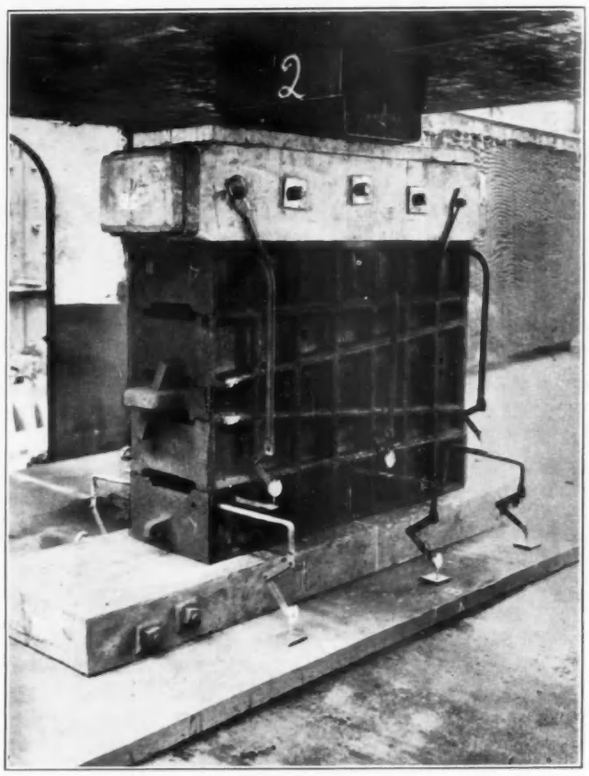
Figs. 9. Steel Monolith-Shoe

diameter steel reinforcing bars, whilst 1½-in. diameter steel reinforcing-bars, securely fastened inside the shoes, were carried up through the courses at the junction of all walls.

After sinking, the bottoms of all wells were carefully cleaned up and a concrete seal, about 13-ft. deep, was deposited through the water in boxes; the three back wells were then filled with earth.

The construction of the superstructure, consisting of concrete covers over wells and gaps, cope-work, pipe-culvert and back crane-beam, was deferred until after the dredging in front of the wall had been done, in order that any "pitching" which might occur to the monoliths should not damage the superstructure.

The original design provided for the monoliths to be sunk to a level of 6.00, or to 30-ft. below dredged level, but considerable difficulty was encountered in attaining this object. Sinking through the first 30-ft. of gravel embankment was comparatively easy, the weight of the monoliths themselves generally being sufficient to carry them down without the aid of much kentledge.



Keel Block ready for Testing

Below the gravel embankment sinking and control presented many difficulties, especially in a bed of firm greensand. Examination by diver revealed the fact that the ground at the bottom of the wells was dished to roughly hemispherical shape, and that the cutting edges were supported on walls of earth under the cant-plates which the grabs were unable to reach. Heavily loading the monoliths with kentledge in the form of large cast-iron blocks was the usual method of weighting them whilst being sunk, and in addition the wells were dewatered by pumps in order to reduce the flotation. The dewatering had to be done with great care, as it tended to cause blows in the wells, which, while helpful under certain circumstances in the earlier stages of sinking, were fraught with risk in the later stages. After trying various methods, two appliances made upon the site were eventually employed with signal success. The first, known as a "scarifier," consisted of a number of vertical 15-in. by 15-in. steel I-beams riveted to form a framework octagonal in plan and of such dimensions that the appliance could pass down the wells with a small clearance all round. The appliance weighed about 10 tons. The other appliance, known as a "surger," was somewhat similar in design, but had the vertical steel I-beams around the outside only, a 1-in. thick horizontal diaphragm-plate being provided, with a 3-ft. square hole in the centre. The function of the "scarifier" was to pound up the firm sand into such a condition that the grabs could easily excavate it, and to this end the "scarifier" was alternately raised by a crane and allowed to drop freely through several feet into the bottoms of the wells. The operation of the "surger" was similar, the effect being

Southampton Docks Extension—continued

that the walls of earth under the cutting edges were worn down by the surge of the water in the wells.

Appliances used in Monolith sinking operations
In the foreground the Scarifier, and in the background, to the left, the Surger

Several of the earlier monoliths were found to be damaged to a lesser or greater extent as the result of the sinking difficulties, and in these all the wells were filled with mass concrete. It was found that very little or no damage occurred before the shoes reached a level of 29.00, or 7-ft. below dredging level, and it was therefore decided to limit the sinking of the remainder of the monoliths to that level, and to compensate for the loss of stability thus incurred by removing the gravel behind and forming it to a slope of 1 in 1½. The triangular void thus formed was covered by a continuous reinforced-concrete slab, 4-ft. 6-in. thick, one side of which rested on the back walls of the monoliths and the other on reinforced-concrete piles. The tops of the latter, together with those for the shed-foundation, were incorporated in a continuous capping beam. This construction, which is shown in Fig. 8, was adopted from monolith No. 15 to monolith No. 146.

The ground between the monoliths was allowed to assume a natural slope, and its surface, with that of the 1-in-1½ gravel slope, was cloaked with rubble limestone for a thickness of about 3-ft. In the earlier stages where the wall had a full backing of earth behind, the gaps between the monoliths were closed by heavy-section steel sheet-piling; from monolith No. 15 westwards, where the gravel slope was formed, the gaps were not closed.

Quantities

Amongst the principal quantities dealt with were:—1,000,000 cu. yds. of excavation; 600,000 cu. yds. of concrete; 8,500 tons of reinforcing steel; 5,000 tons of steel in monolith-shoes.

Quay Cranes

The quay is equipped with twelve 5-ton and sixteen 2-ton portal level-luffing cranes, all operating at 86-ft. radius. The crane-gauge is 18-ft.

The 5-ton cranes have electric floating-brake control on the hoist-motion. The speeds are:—

Hoisting	100 feet per minute
Travelling	50 ,, ,, ,,
Luffing	120 ,, ,, ,,
Slueing	0·9 revolutions per minute

They can lift 2½ tons at 200-ft. per minute.

The 2-ton cranes are of the free-barrel type with contactor operation for the hoist-motion. The speeds are:—

Hoisting	200 feet per minute
Travelling	50 ,, ,, ,,
Luffing	160 ,, ,, ,,
Slueing	1·1 revolutions per minute

Cable-Culvert

A culvert for the accommodation of electric cables, water mains, etc., is provided, as shown in Figs. 7 and 8.

(To be continued).

Publications

The Report of the Rotterdam Chamber of Commerce for 1937 has been issued in English in an abridged form. It is customary for the Chamber to publish an annual statistical review of the commerce, industry and traffic of the port and the present issue, judging from the contents for the whole production, is a comprehensive account of those features for the year in question. The English abridgment commences with an introduction in which it is stated that the hope of an improvement in business confidently anticipated from the relaxation of the political situation had been "destroyed in many quarters." At the same time, "the considerable increase of goods traffic all over the world has caused the Rotterdam port figures also to rise a great deal."

The following figures are given of the shipping traffic by sea in 1937 in the three largest Western-European ports (the figures in brackets relating to the year 1936):—

	Number of Ships entered	Register tons net
Antwerp	12,386 (11,429)	20,592,000 (18,895,000)
Greater-Hamburg ...	18,663 (16,720)	19,745,000 (19,216,000)
Rotterdam	14,375 (12,623)	23,750,000 (20,572,000)
New Waterway ...	16,154 (14,284)	26,188,000 (23,247,000)

Allusion is made to the unfavourable effect of the Belgian Rhine Navigation Premiums and to the continued diversion of German goods or goods destined for Germany to the German North Sea ports to the detriment of Dutch and Belgian ports alike.

Canadian Ports and Shipping Directory, compiled by Frederick William Wallace, and published by National Business Publications, Ltd., Gardenvale, Que., Canada, contains all essential information respecting Canadian ports and shipping services for the use of shipowners, brokers, charterers and shipmasters interested in trade with Canada. The ports are listed in alphabetical order, the information regarding each port being grouped under definite heads. The particulars given include location, navigation season, towing facilities, accommodation, channel depth, port charges, etc., as well as reference to railroad services and other available forms of transport. There are six appendices, relating to the River St. Lawrence, the Bay of Fundy Harbours, British Columbia, the Great Lakes and to special Tariff dues.

Tramp Shipping.—There has been received the Sixth Report of the Tramp Shipping Administrative Committee (published by H.M. Stationery Office, price 6d. net). It marks the close of the period of availablity of Government subsidy and the inauguration of a system of co-operation on a voluntary basis. Much concern has been felt in shipping circles at the depression which has overtaken the tramp shipping industry, but the attitude of shipowners at the present time is that the voluntary scheme should suffice to enable the industry to maintain its ground. The Report has been presented to Parliament by the President of the Board of Trade.

Transportation on the Great Lakes.—A copy of the 1937 edition of this publication has been received from the Board of Engineers for Rivers and Harbours, United States of America. The report contains a description of the Great Lakes and their connecting channels and harbours, and gives information relating to laws, treaties, and regulations concerning navigation and traffic. It shows in considerable detail the development of commerce and shipping on the Great Lakes, the major portion of the volume being devoted to an intensive study of the movements of the important bulk commodities, grain, iron ore and coal and of the terminal facilities available for handling these commodities. The movements of stone, petroleum, forest products, sand and gravel, and cement are also shown, and information is given concerning the commodities handled and the tonnages of package freight, the lines engaged in package freight service, and the terminals for handling this traffic. The car ferry service is also described and information given regarding the traffic handled. Numerous graphs and charts showing the movementts of the various commodities handled are presented in the report, and many illustrations are given of important grain elevators, bulk freight terminals, various types of vessels, equipment for loading and unloading, etc.

Notes of the Month

Contracts from the U.S.S.R.

The Government of the U.S.S.R. have awarded contracts to Messrs. Fleming and Ferguson, Ltd., of Paisley, Scotland, for three self-propelled steam hopper barges, each of 800 tons capacity, and also for a powerful type of dipper dredge for river work.

Rhine-Danube Shipping Thoroughfare.

The German Government have published a law which decrees that the Rhine-Main-Danube Canal shall be completed by 1945, and that the Danube below Vienna shall be deepened and developed as a thoroughfare for vessels up to 1,500 tons. It is anticipated the work will cost about 750 million reichsmark.

Two New Dry Docks for Mexico.

Plans for establishing two dry docks, one on the Gulf Coast and the other on the Pacific Coast, are being drafted by the Mexican National Defence Ministry. The docks will be capable of accommodating vessels up to 1,200 tons, and will be available to merchant as well as naval vessels. Ulna, a small island in Vera Cruz Harbour, has been chosen for the Gulf dock, and the site for the Pacific dock is to be selected by a naval commission.

Harbour Scheme for North China.

A plan for port and harbour construction in North China, to be undertaken by the projected China Communications Company, is being studied by Japanese authorities. The principal ports in that region are Tientsin, including Tangku, Chinwangtao, Tsingtao, and Lienyun, near Haichow. The enterprise is held to be necessary in connection with railway extensions in hand, and as a large amount of capital will be required, at the moment the work will be confined to expanding existing equipment.

Trade at Port of Churchill.

The National Harbours Board of Canada in its annual report for 1937, makes the following statement: "Movement of grain at Churchill, which has been almost the entire traffic of the port, was adversely affected by short crops of 1936 and 1937. Only two cargoes of wheat were exported in 1937. No grain was received, and the terminal elevator is practically empty. As in each of the five previous years, only one ship brought a cargo of general freight from Europe. Due to reduction in expenditures, the net loss on the operation of Churchill in 1937 was $141,913, compared with $196,014 in 1936, no charge being made for interest or depreciation."

Harbour for Sark.

The Harbour Committee in the Island of Sark have notified Sir Lindsay Parkinson and Co., Limited, that their tender for the construction of a harbour in Maseline Bay, in the Island of Sark, has been accepted. The work consists of the construction of a concrete block breakwater built on a prepared concrete foundation on the sea bed. The height of the breakwater from quay level to foundation is 55-ft., and the depth of the water alongside at high water of spring tides is 49-ft. The first work to be done is the construction of an approach road to the breakwater consisting of rock cutting in the face of the granite cliffs, including a bridge and tunnel through the point known as Les Cagnons. An early start will be made with the work, which will take two years to complete.

Harbour Development in Northern Ireland.

The Minister of Finance in the Government of Northern Ireland area has announced that it has been decided to give assistance to the extent of £225,000 towards the cost of the deepening of part of the channel of Belfast Harbour. The total amount of expenditure involved in the scheme is £400,000, and the object is to enable Messrs. Harland and Wolff, Limited, to undertake the construction of the very largest size of merchant ships and battleships. The Harbour Commissioners are unable to provide the full sum from their own resources, and the Government have, accordingly, undertaken to give the amount mentioned. It is intended to proceed with the work immediately, and the payments will be spread over a period of years. The Government have also decided to assist to the extent of £20,000 in the financing of extensive harbour deepening works at Londonderry Harbour to enable ships of deeper draught to reach the port. This work has already been begun, and its completion will greatly improve the accessibility of the River Foyle. Coleraine Harbour Commissioners are to have £6,000 for a similar purpose. Coleraine is a progressive port, which maintains regular cross-channel sailings to England and Scotland, and is the centre of an important importing and exporting area.

Extensions at Port of Dakar, Senegal.

Work is about to be commenced on an extension scheme at the Port of Dakar in French West Africa. It is proposed to join the southern part of the island of Gorée to the mainland, and to make the entrance to the port at the north of the island. It is anticipated the work will take 18 months to complete.

Foreign Orders for the Clyde.

Another contract for a powerful self-propelling steam cutter suction and refouleur dredger has been placed by the U.S.S.R. with Messrs. William Simons and Co., Ltd., of Renfrew, Scotland. This is a repeat of an order received from Russia a few months ago. The design of the vessel will incorporate several special features.

Deep Water Harbour at Röytta, Finland.

The Town Council at Torneå is seeking a grant of 10,000,000 marks towards the cost of constructing a modern deep-water harbour at the Port of Röytta. It is estimated that the cost of the harbour will amount to 14,500,000 marks, and in addition, the administrative buildings and warehouses will cost a further 1,500,000 marks.

Manchester Ship Canal.

The approximate traffic receipts of the Manchester Ship Canal for May amounted to £104,325, compared with £111,000 for May, 1937. The aggregate receipts for the first five months of this year were £511,821, a decrease of £1,238, compared with the corresponding period of last year.

New Quay for Montreal.

Tenders are about to be invited for a new high-level quay to cost approximately $200,000. The new quay is designed for bulk cargo, and it is hoped to divert to it some of the coal traffic from other quays. The wood pulp industry, which has developed considerably during the past few years, may also be centred at this new long quay, which will be raised 10-ft. above water level, and will be over 1,000-ft. long.

Pilotage on the Tyne.

At a recent meeting of the Tyne Improvement Commission in Newcastle, a proposal from the Tyne Pilotage Authority for compulsory pilotage was rejected. The Harbour and Ferry Committee recommended the provision of a wireless beacon for the assistance of vessels making for the Tyne, the question of location and range to be decided when further information has been received.

Port of Montreal Tariff Changes.

American and Canadian grain exporters are reported to have withdrawn all quotations abroad on shipments through the Port of Montreal because of the changes made by the National Harbours Board in the tariff on grain exports from Montreal. The Board has decided that grain exports must pay the outboard elevation charges on wheat shipments, instead of the steamship companies, as has been the custom for the past fifty years. The cost is $4 for 1,000 bushels.

Breakwater Repairs at Aberdeen Harbour.

On the recommendation of its Works Committee, the Aberdeen Harbour Board has approved a scheme of repairs to the South Breakwater at an estimated cost of over £80,000. Last year, a breach which was torn in the breakwater by storms, was repaired at a cost of more than £30,000. Mr. H. Barr, the Harbour Engineer, has reported that the work necessary to restore the efficiency of the breakwater can best be effected by the construction of a new face wall on the seaward side of the structure and the covering of the existing work with a new concrete surface. It is anticipated the work will take about four years to complete, as operations will have to be suspended during the winter months.

Dock Improvements on the Tyne.

Newcastle Corporation Trade and Commerce Committee has recommended that application be made to the Minister of Transport for sanction to borrow £43,116 for quay works and £27,500 for the purchase of land at the Close. Work in connection with the Corporation's new 930-ft. quay has been carried out for a distance of 630-ft., and sanction is now sought for further sums for the completion of the quay. Elsewhere on the Tyne other improvement schemes are under consideration. South Shields Corporation has an important scheme in hand for the construction of a deep-water quay, and the Tyne Improvement Commissioners have adopted plans estimated to cost over £800,000 for the development of the Tyne Dock and the provision of further quayage and cargo-handling facilities.

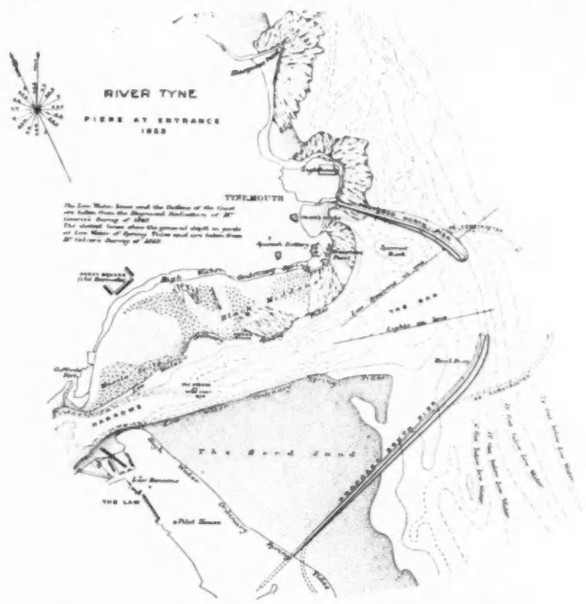
*Estuary Channels and Embankments**

By BRYSSON CUNNINGHAM, D.Sc., B.E., F.R.S.E., M.Inst.C.E.

(concluded from page 239)

Harbour Entrance Jetties.

Although training walls, as already described, can be, and are, applied in outer estuaries to the formation or improvement of a navigable channel through a bar, the circumstances generally require some difference in design. In cases where a bar, or for that matter a troublesome shoal, is in close proximity to the river mouth and lies directly in the fairway of vessels making for the port, jetties or piers of various types of construction have been projected out from the shore-line, the lower part of the structures being solid work so as to confine and direct the effluent stream. It has generally been found, however, that though in this way some temporary improvement may be effected, the bar or shoal has a tendency to re-form a little further out, necessitating the extension of the jetty to remedy the evil. The process of extension has, in fact, to be continued until the jetty reaches water of sufficient depth to render the shoaling inappreciable, or to bring it within the influence of littoral currents of sufficient strength to prevent the possibility of deposit. It has also to be borne in mind that the projection of a solid work from the coast line usually induces accretion on one, or possibly, both sides, often attended by local erosion in addition, both of which processes may be extremely inconvenient and detrimental. These aspects of littoral drift, however, scarcely come within our purview.



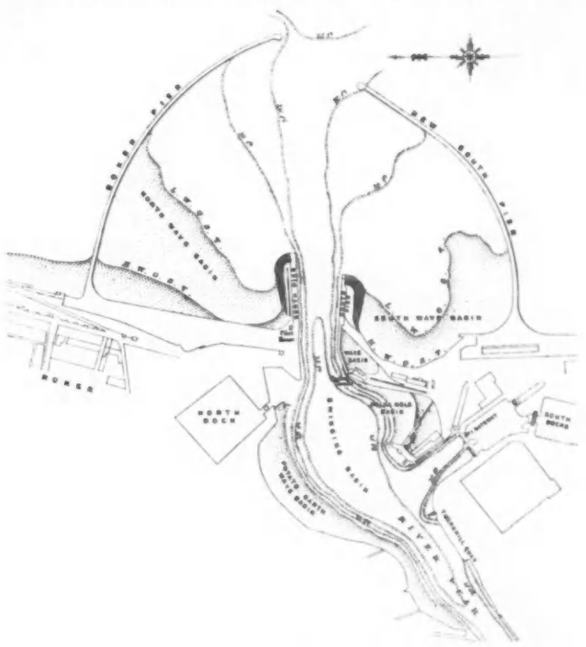
Convergent Piers at the Entrance to the Tyne

The Mouth of the Tyne

Jetties, or piers, for directing and strengthening the outgoing current have been constructed at several French ports in the English Channel, and they are also to be found at certain English ports on the North-east coast as, indeed, elsewhere. By way of illustration, we will refer to the two convergent piers at the entrance to the Tyne. The distance between the two pierheads is 1,180-ft. Initiated in 1853, under the conditions shown on the plan attached to a Paper† by Mr. R. F. Hindmarsh, (reproduced above) and primarily directed to the removal of a bar, they were also designed to afford interior space for the dissipation of heavy seas. Between 1898 and 1908, a considerable portion of the North pier had to be re-constructed in consequence of the collapse of the outer portion. In 1908, statutory powers were obtained to dredge the navigable waterway of the river, and the work has since been proceeding continuously, with the result that in place of a depth of 6-ft. at L.W.O.S.T. over the bar in its natural state, with a winding channel beset with reefs and shoals, there is now a standard depth of about 30-ft. from the sea to Northumberland Dock—a distance of over three miles. Vessels can enter and leave the harbour with draughts of as much as 33-ft. In order to achieve this result, over 160 million tons of material have been dredged and taken to sea.

The Mouth of the Wear

To take another instance, at the mouth of the Wear (vide plan on this page) two parallel piers were constructed between 1832 and 1843. Subsequently, the bar re-formed at their outer extremities, usually extending from the Northern pierhead to a point some 300 or 400-ft. eastwards. Between 1883 and the commencement of the present century, a couple of outer projecting piers, or breakwaters, semi-circular in plan, were added, providing an entrance width of 700-ft. between their pierheads. As in the case of the Tyne, the works were designed very largely to deal with the swell which entered the harbour in stormy weather.* Under the new conditions the bar has disappeared. In the course of channel deepening operations, it was discovered that the site of the old bar was largely occupied by reefs and pinnacles of magnesian limestone, which combined to form a natural barrier at which drift material accumulated. A further interesting fact is that it is precisely in this area that silting continues to take place and the bar tends to re-form, being kept under control, however, by dredging. There appears to be no tendency towards shoaling between the outer pierheads, but rather the reverse. The present depth in the navigable channel is 20-ft. L.W.O.S.T.



Entrance to Sunderland Harbour

The Mouth of the Tees

We may take a third and final illustration from the mouth of the Tees, a river with a remarkably wide, sandy estuary, extending several miles inwards from the sea.

Both training works and dredging have been employed to improve the navigable channel and, at the present time, an important programme of reclamation is in progress at Seal Sands, where a timber revetment has been constructed along a part of the Northern bank of the river, and is destined to be prolonged in a curvilinear form to the high water embankment at the landward end of Seaton-on-Tees Channel.

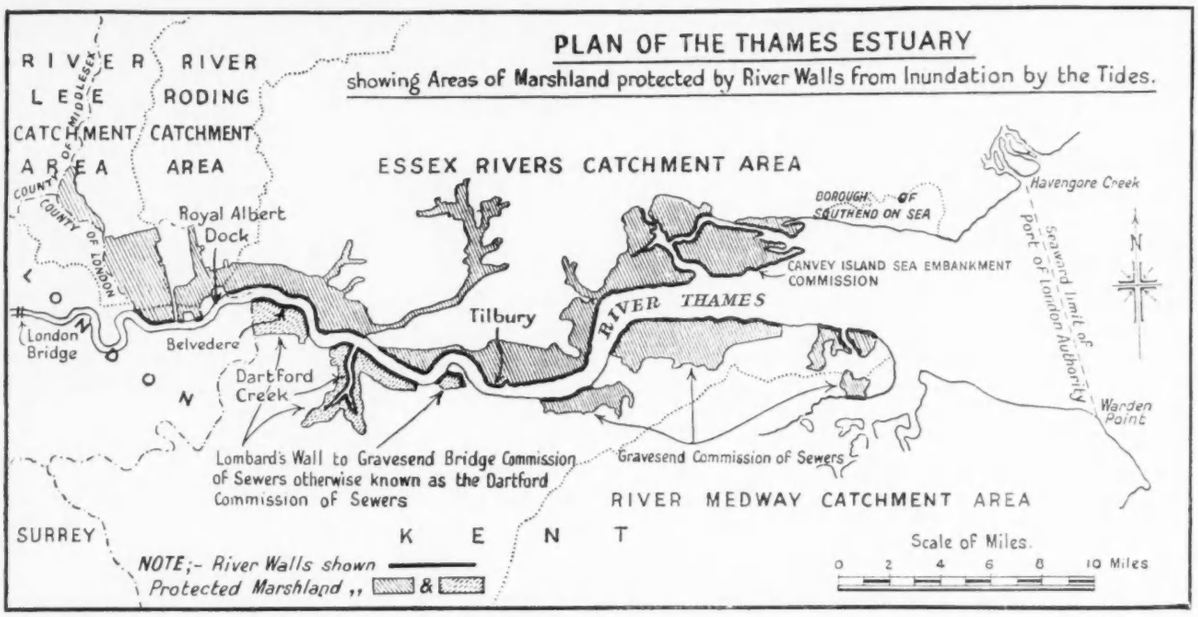
The entrance of the river is protected by two converging breakwaters, known as the North and South Gare Breakwaters, constructed in the latter half of last century, with a distance of approximately 4,000-ft. between their outer pierheads. These breakwaters are embankments formed of large blocks of slag, faced on top with concrete. By concentrating the scour of the current across the bar, they have effected a considerable reduc-

* The 1937-8 Vernon-Harcourt Lecture of the Intsitution of Civil Engineers, delivered at the Institution on December 8th, 1937, and subsequently repeated at Manchester, Newcastle, Sheffield, Birmingham, Glasgow, Belfast, Cardiff, Bristol and Southampton.

† The Design of Harbour and Breakwaters with a view to the Reduction of Wave Action within them," Proc. Inst. C.E., Vol. 209 (1919).

* The Improvement of the Entrance to Sunderland Harbour by Wm. Simpson, Proc. Inst. C.E., Vol. 209 (1919).

Estuary Channels and Embankments—continued



tion of its crest, so that, in conjunction with dredging operations carried out under the direction of Mr. P. A. R. Leith, there has been achieved a depth of 45-ft. below L.W.O.S.T. at the entrance, and a depth of 25-ft. below L.W.O.S.T. at the Fifth Buoy, rising to 22-ft. below L.W.O.S.T. at the London and North Eastern Railway Company's Dock Cut at Middlesborough.

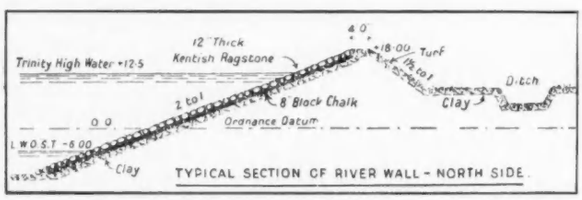
ESTUARY EMBANKMENTS

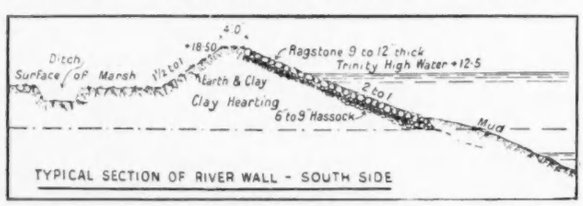
We must now give consideration to another department of estuarial work which involves no less care and attention than channel training. Many rivers discharge into the sea through flat, low-lying land which would be subject to flooding at high water of certain tides, were it not protected by artificial means. Moreover, there are whole districts in the marine provinces of Holland, where the level of the land is permanently below sea level. Under these circumstances, the construction and maintenance of flood protection works becomes an important part of the responsibilities of the engineer in charge of a river estuary.

Thames Estuary Embankments

At the mouth of the Thames, there are more than 40,000 acres of estuarial marshland in the counties of Kent and Essex requiring protection, for the reason stated. Part of the land is cultivated, extensive portions are built upon and the remainder is used for the grazing of cattle. Moreover, a considerable number of factories and industrial works have established themselves along the river frontage under the cover of the protection afforded by the embankments, which serve not only for this purpose, but also during periods of high tide confine the river within the limits of its navigable course.

The embankments extend along the river on both sides for a distance of nearly 50 miles, from just below London Bridge to the sea. Historically, considerable portions of them are of great antiquity, going back, it is reasonably conjectured, to Saxon or even, possibly, to Roman times. They have been reinforced so frequently and extended during the centuries, that the sums of money expended upon their construction and maintenance must reach an enormous total.





River Thames Embankments

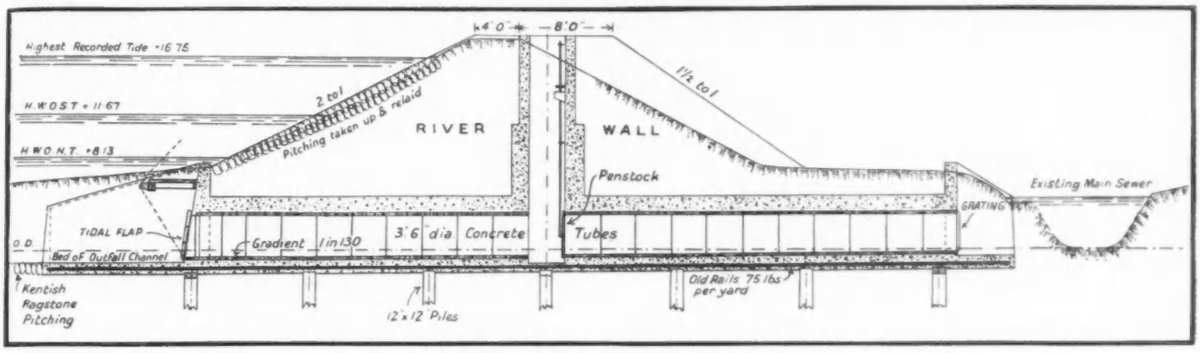
The "walls," as they are termed, are embankments of earth with a core, or hearting, of puddled clay, protected on the river side from wave action and the wash of passing vessels by means of a revetment or pitching of stone. The diagrams below show typical sections on both sides of the river. The marshland level is generally from 12 to 14-ft. below the top of the walls. The crest or summit width is from 3 to 5-ft., and usually forms a

Intake of Sluice in Thames River Wall

footpath for pedestrians. The standard slopes are 1½ to 1 on the landward side, and 2 to 1 on the river side, though the actual slopes in most places are either steeper or flatter than the standard.

For land drainage purposes the walls are pieced at intervals by sluices, through which land water is discharged at low tide. Formerly, these sluices were constructed of timber, and the outlets were protected only by a hinged flap. During recent years, while acting as Engineers to the Dartford Commission of Sewers, a statutory body which controls about 19 miles of river and creek frontage, Mr. Havelock Case and myself, during our partnership, renewed several of these sluices on the Kent side of the river in concrete tubes, with a central shaft of concrete containing a geared penstock, so that in the event of any stoppage or defect in the outer tide flap the intake can be controlled by the penstock. Since the dissolution of partnership, I have continued the process, and at the present time have two sluices in course of construction for the Kent Rivers Catchment Board, the successors of the Dartford Commission of Sewers.

Estuary Channels and Embankments—continued



Section of Sluice, Thames River Wall.

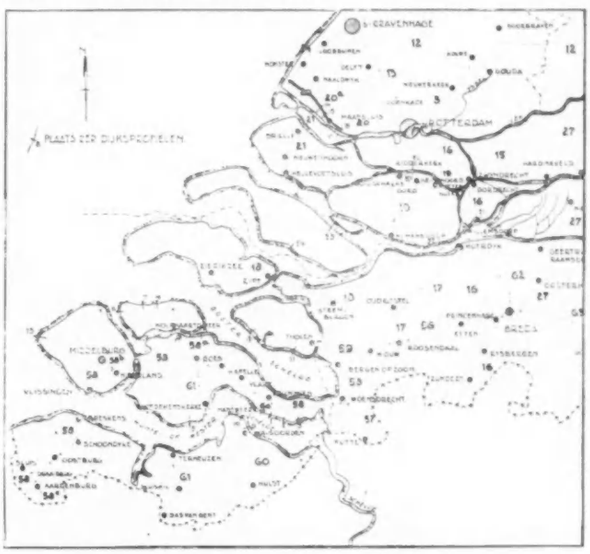
The walls are in constant need of replenishment with fresh material. There is more or less continuous settlement on account of the compressibility of the subsoil, which is mainly peat and alluvium. There is also degradation under atmospheric influences, and wear and tear due to pedestrian traffic and cattle, besides the depredations of vermin. Sometimes slips occur, which may be troublesome to arrest. In one case, recently, a portion of wall, over 200-ft. in length, subsided as much as 12-ft. within a few weeks. Various means have been taken to check these movements, including, in certain places, the use of sheet piling with anchorages in the rear. In open situations, however, the wall can generally be reinforced by building up on the inner side, or in more serious cases, an entirely new inner wall has been constructed.

The earth, or soil, is taken from the marshland or the external saltings, the core being generally made up of stiff, uncallow clay from the top spit of chalk quarries in North Kent, sometimes with the addition of a hard, coarser clay from the London area. The stone used in the Kent walls is ragstone from local quarries, a very hard durable stone, laid on an underlying bed of hassock, which is a softer and more friable stone found bedded in alternate layers in the same quarries. On the Essex front, hand-picked block chalk is largely used. Concrete slabs and tiles have also been tried, but they are more expensive, and the advantage of stone blocks is that they yield without fracture in the event of settlement.

The standard height of the walls in North Kent is 18-ft. 6-in. above old Ordnance Datum, or 17-ft. 6-in. above Newlyn Datum, or again 6-ft. above Trinity High Water, frequently used as a datum in the Thames. This allows a fair margin above maximum tidal height for wave action. On the Essex side, the standard is 6-in. lower. The highest tide in recent years was that of the 6th-7th January, 1928, which indeed constitutes a remarkable record, due to an exceptional combination of causes. There was an abnormally high spring tide, accentuated by a storm surge in the North Sea, combined with a rush of water down the river arising from heavy rainfall on the frozen surface of the Thames Valley. On that occasion the river walls were overtopped in a few places.*

It is interesting to note that the instances of wall failure, so far as they came under my observation, were attributable not to overturning but to excessive hydrostatic pressure at the inner toe of the wall, aided by infiltration of water. This caused a slip or cleavage on the inner side, first near the base, then as portions of the backing fell away, upwards to the top. The frost which accompanied the rain of the date of the tide in question had undoubtedly increased the porosity of the material.

In comparison with the Thames river walls, the foreshore tidal bank on the River Trent is formed in the first instance with successive deposits of chalk and slag, behind which accretion and warp filling take place, giving support to a crest of earthwork at the top of the bank.

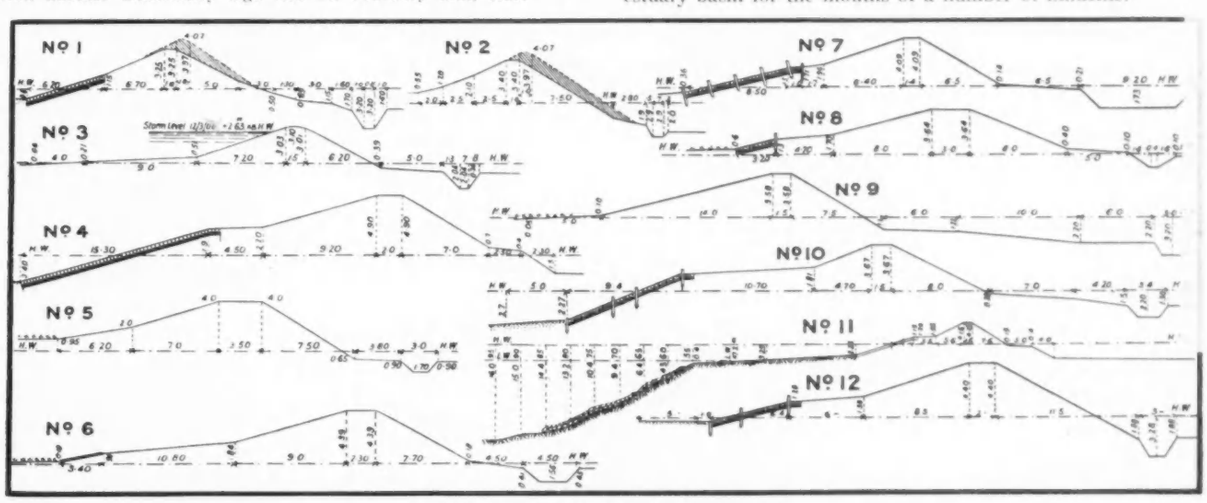


Mouths of the Scheldt and Maas

Netherlands Embankments

The estuaries of the Scheldt and Maas form a network of waterways, and abound in tidal flood protection embankments of a great variety of types, a number of which are illustrated at the foot of this page. These embankments are constructed either entirely of clay, or where that material is scarce, with a core or hearting of sand and a covering layer of clay. In more important cases, the banks are built up, in part at any rate, with fascine mattress work, which is an important component of the main dyke, or embankment, formed in connection with the Zuyder Zee reclamation scheme, now creating a great estuary basin for the mouths of a number of influents.

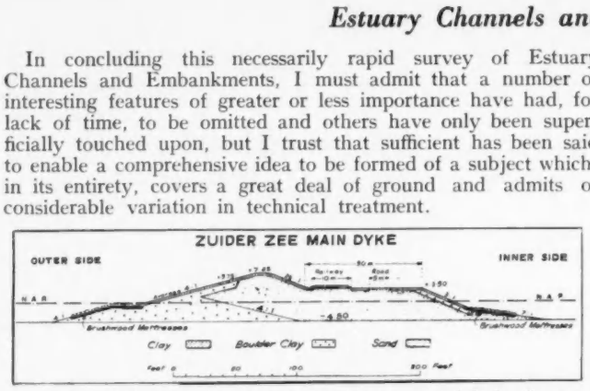
* Since this lecture was prepared in the autumn of 1937, there has been another abnormally high tide on February 13th, 1938.



Tidal Embankments in the Netherlands

Estuary Channels and Embankments—continued

In concluding this necessarily rapid survey of Estuary Channels and Embankments, I must admit that a number of interesting features of greater or less importance have had, for lack of time, to be omitted and others have only been superficially touched upon, but I trust that sufficient has been said to enable a comprehensive idea to be formed of a subject which, in its entirety, covers a great deal of ground and admits of considerable variation in technical treatment.



I have much pleasure in expressing my grateful thanks to a number of friends and professional colleagues, who have kindly placed at my disposal, plans, photographs, slides and information for the purpose of this lecture. In particular, I desire to mention Sir David Owen, General Manager, and Commander E. C. Shankland, R.N.R., Harbour Master, of the Port of London Authority; Vice-Admiral Sir H. P. Douglas, K.C.B., C.M.G., Acting Conservator of the River Mersey; Sir Lionel Warner, C.B.E., General Manager, and Captain H. V. Hart, Marine Surveyor of the Mersey Docks and Harbour Board; and the following Members of the Institution: Dr. Herbert Chatley (late Whangpoo Conservancy Board), and Messrs. A. C. Gardner (Clyde Navigation Trust), W. H. Haile (Trent Catchment Board), A. H. Howarth (Ribble Navigation), P. A. R. Leith (Tees Conservancy), and W. H. S. Tripp (River Wear Commission). I am also indebted to several Engineers abroad, including Monsieur Lévêque (Bordeaux), now Inspecteur Général of the Ponts et Chausseés (Paris),

Zuider Zee. Construction of Dyke.

Dr. Van Veen, Professor Klopper, Heer Mouton (The Hague), Heer Koomans (Rotterdam), Monsieur Barrillon (Rouen), and Professor Ferro (Padua) for similar esteemed assistance.

*Harbour Accommodation**

Services and Charges in Relation to Coasting and Overseas Trade

By H. HOPPERTON, M.Inst.T.

The Discussion

Mr. D. Ross-Johnson, a Vice-President, who occupied the chair, observed that Mr. Hopperton had the exceptional advantage that he had taken part in the operation and administration of railway-owned docks, of a dock commission, of a municipal dock, and now he was the general manager of a statutory company's stock, so that he had had an all-round experience. Incidentally he might add that Mr. Hopperton was also a Provost of Ardrossan, the port at which he was now working.

On the motion of the Chairman a hearty vote of thanks was accorded to Mr. Hopperton for his paper.

Mr. P. de Malglaive, M.Inst.T., in opening the discussion, said he was in agreement with all the views expressed by the author in his paper. What shipowners wanted was a harbour with easy access, good quayage and docking facilities, good facilities for handling cargo, and very low costs. He had been very much interested in the author's suggestion that the signals for docking should be standardised for the whole of the ports of the country. It was absolutely imperative to have the same signals operating at all ports. It was unfortunate in his view that port authorities had no jurisdiction over maritime signals or the control exercised by the Board of Trade in the matter. He thought it would be very helpful if the port or dock authorities had more direct authority with respect to wireless signals, beacons, and so on. He recalled the great difficulties experienced in the installation of wireless signals and beacons at two Channel ports; it had only been after very prolonged discussion that they had been installed, and at one of those ports the installation had been carried out by a railway. In fairness to everybody he thought such essentials should be provided by the Board of Trade.

He agreed with the author's statement that net register tonnage was wrong as a basis for dock charges. In the first place it was not computed in the same way in each country. No doubt the story of the "Leviathan" would be well known. After the war when she was measured by the Americans she gained over 10,000 tons in net register tonnage. When business was bad a few years later she was measured again and her tonnage went down 12,000 tons. That showed that net register tonnage was not a very good basis for computing charges. It would be much fairer to find a formula which took into account the business transacted and the time involved. The best gauge was the draught of a ship coming in and out, and he believed that that would be the best basis for the computation of harbour dues.

The time factor was very important. Harbour authorities had been severely tested by having to provide for the increasing size of ships, and it was to be hoped that the limit had nearly been reached—for freight boats at any rate. He did not think a freighter of more than 10,000 tons could be run economically, and if harbour authorities provided accommodation for such a tonnage for freighters he believed it would be sufficient for quite a long time. For passenger liners it was a different matter, and in that respect it might be well for the authorities at Southampton and at other places to look far into the future.

Mr. M. Salt, M.Inst.T., remarked that as he was more particularly interested in coastwise shipping he was rather intrigued as to what Mr. Hopperton meant when using the phrase "coastwise shipping": did he mean merely British coastwise shipping or did he include the home trade such as shipping running between the Elbe and Brest? It was often called coasting but it was not purely British coasting. Again, it could be divided into tramps and liners. The tramps were very much in competition with one another, and to a certain extent with the liners, and both were more or less in competition with the railway companies. These points had to be borne in mind because they had a distinct bearing on some of the questions raised in the paper.

He was entirely in agreement with the author's views respecting statutory powers; as a matter of practice harbour authorities did make a difference in the charge for vessels going small distances, but there was no difference in the charge, so far as he knew, whether a vessel stayed in port for one day or for thirty days. Something might be done in that connection. It was very difficult to find a really true basis for charging tonnage dues. Harbour dues were composed of many charges. Tonnage dues—and the actual dock dues—were generally computed on the net register tonnage, and it was not easy to find a fair way of computing the whole set of charges. The suggestion had been made that there might be a difference in the charge according to whether the cargo happened, for instance, to be gold or grain. It was true that there might be a very large difference in the actual freight between one cargo and another, especially if one happened to be a general cargo; but in a general cargo it was necessary to take into consideration the whole of the overhead expenses—the expense of canvassing for and securing the cargo, and incidental expenses and charges, which probably in the long run left less remuneration than a bulk cargo, say, of coal.

His views on the subject of docks being used to their full capacity coincided with those of the author, and he doubted very much whether it would be advisable to increase the capacity of many of the docks. It had been done more particularly to suit local trades. Dock authorities were undoubtedly limited by the problem of finance and they were constrained to adopt a business point of view. As one port was competing with another he did not see how it was possible to have the same standard for port dues for each port; some cost more and some cost less. For instance, at one particular port in which he was interested there were no cranes for general cargo. The authorities had

* Supplement to the Paper of this title, read before the Institute of Transport on February 14th, 1938, and published in the May issue of this Journal.

Harbour Accommodation—continued

been requested to instal such cranes and they had immediately replied to the shipowner, "If we do, will you give us a guarantee that you will use them?" The shipowner replied, "Well, we want them there, but it is usually cheaper to use our own winches and derricks"; the guarantee was, therefore, not forthcoming. Then with regard to despatch, taking cargoes of coal from the Tyne to London, if 72 hours were given for all purposes it often happened that actual loading and discharging only occupied half that time. From the Humber to London 36 hours were given for discharging. Very often it was discharged in 4 or 5 hours, but the 36 hours must include the waiting for a berth. It was usually to a nominated berth, and it was necessary to wait until the berth was ready. Even so, that was all taken into consideration in the rate of freight.

On the whole, seeing that ports were in competition with one another, he thought perhaps it would be just as well to let them work out their own salvation so far as their requirements—financial and otherwise—were concerned. He believed, however, that some action might be taken respecting tonnage dues, whether on N.R.T. and being charged at so much per day, instead of for 30 days as at present.

Mr. J. H. Hannay-Thompson, M.Inst.T., thought that one of the most valuable facts to which the author had drawn attention was that the regular and the casual trades in a harbour represented two individual problems from the point of view of the harbour authority. The position of ports in the transport world was almost unique in that, from their nature, they were entirely dependent for their welfare on external factors over which they had no control. Fluctuations in trade had a relatively small effect on their expenditure, and that was the reason why in times of bad trade harbours presented as a rule an unsympathetic ear to shipping interests when the latter called for reductions. Harbour charges were rarely made strictly in accordance with the services rendered but, like the railway companies, the harbours scaled their dues in accordance with what traffic would bear. In some harbours the rates were uniform, but others showed very marked differences—particularly the harbours of the East Coast of Scotland. Thus the tonnage dues in Dundee and Leith were 2d. per net register ton for coastal vessels and rose in accordance with the distance from port of origin or destination to as much as 2s. 6d. per N.R.T. In fixing these rates, although time was not actually taken into consideration he thought there was no doubt that the time berths were occupied by the large vessels had been subconsciously or perhaps unconsciously considered. In the same way there was a marked disparity in the rates on goods. Coal was as low as 2d. or 3d. per ton. Grain—to take an intermediate commodity—in Leith and Dundee was about 1s. For luxury articles as much as 7s. a ton might be charged. With regard to the question of different charges per N.R.T. for different cargoes, at Leith coal cargoes had special terms. Granton Harbour, with which he was associated, situated 2 miles from Leith, had been built about 100 years ago and was still one of the few harbours which was in private ownership. It handled a trade of about 750,000 tons annually, and specialised in bulk commodity trades carried exclusively in tramp steamers, and trawling. Granton gave a rebate after ten voyages had been made by the same vessel; but though the dues on foreign vessels were reduced from 1s. per ton to 2d., and on coastwise vessels from 3d. per ton to 2d., no attempt was made by these tramp lines to avail themselves of the reduction by placing one vessel continuously upon the run—presumably because the benefit offered by the reduction in dues was small as compared with other factors such as suitability of the vessel for individual cargo. The same he understood to be true of the neighbouring port of Leith where only the lines which had passenger services and regular advertised sailings strove to benefit by the reduction. He had also prepared figures to compare with those given in the author's Appendix 2. Granton Harbour had a commercial quay space of 4,700 lineal feet, and its total revenue on vessels and goods per day per foot of quayage worked out at $2\frac{3}{4}$d. This was due to the very low level of its charges, and was in spite of the fact that its berths were occupied from 40 to 50% of capacity. Its dues were still those laid down in the Granton Harbour Act of 1837, and they had never since been changed. He entirely supported the author's contention that the present method of charging dues was based on antiquated conditions and that the time was ripe for a reconsideration of the basis, particularly in view of the past and future changes in ship design.

The suggestion that time of occupancy should be a factor was most attractive, particularly for a congested harbour which wanted to put an added spur on the ships to get a quick turn round, but it would have to be remembered that in a harbour which was not quite so busy a vessel must pay the harbour not not only for the time during which it occupied the berth but also for the time the berth would remain unoccupied until the vessel's place was taken by another. That obviously was the reason for the extraordinarily large reduction which was given to regular traders in one of the items which the author specially mentioned. Many people failed to grasp the point which the author stressed of the casual nature of the use which was made of port services. Granton itself rarely got more than two weeks notice of the probable arrival of a vessel and, in consequence, had no absolute certainty that its trade might not completely cease one month hence. In a smaller measure the same uncertainty applied to larger harbours and, although facilities were costly to provide, they were not generally remunerative and they appeared to be liable to abandonment at short notice even by shipping companies which had employed the facilities of the port with regularity for a considerable number of years. In spite of this uncertainty a harbour was expected to have ready waiting facilities for the accommodation of a vessel which might give only 24 hours' notice of its expected arrival and might never return. Mr. Hopperton had done a great service in drawing attention to the failure of many ports to recognise the value to them of those trades and shipping lines which, by the regularity of their sailings, relieved a harbour of a measure of this uncertainty.

Mr. A. G. Course, Assoc.M.Inst.T., said the author had, very rightly, refrained from mentioning anything concerning the regulations of the net register tonnage, and he might be interested to hear that Dr. Bruhn, speaking about net register tonnage at a meeting of the Institution of Naval Architects as long ago as 1925, said: "Due to the continuous scientific increments to the original system introduced by Mr. Moorsom, a complete Chinese puzzle has been created. At some time a change will, however, have to be made, whereby even tonnage regulations must be brought into line with modern practical requirements; and the longer the change is put off the more inconvenient it will be when it comes."

One subject which had not been mentioned was the International load line which came into force in 1932. That had made a great difference in some instances to the cargo-carrying capacity of vessels under the same net register tonnage. British oil-tankers received the greatest benefit. He had discovered that an oil-tanker of approximately 450-ft. in length carried about 750 tons more oil on her new load-line, but the net register tonnage remained the same.

Further, on the question of net register tonnage, he possessed figures comparing the British system with the Suez and Panama Canal authorities' systems. He had gone aboard two ships which had been alongside each other, and he had found that in one case the British net register tonnage was 4,497, the Suez Canal was 6,337 and the Panama Canal was 6,854. In the other case the British figure was 3,753, the Suez 5,681, and the Panama 6,087. It must be agreed that there was something wrong with a system which allowed of such variable application.

Then there was the bugbear of the open shelter deck with which was not included in the net register tonnage, although the cargo stowed in it was measured and added to it. He believed that according to the method which the Suez Canal adopted, once a ship had carried any cargo in an open shelter deck the full tonnage on that shelter deck was charged. After the international load-line had come into force in 1932, many interesting events had happened. Several Swedish ships which had had permanently closed shelter decks previously, became—after slight structural alteration—open shelter deck vessels and secured a corresponding reduction of 1,000 tons in their net register tonnage. There was the classic case, already mentioned, of the "Leviathan." In 1931 her net register tonnage was 27,696; in 1934 it was 15,796. No structural alterations had been made to the ship; she was just the same responsibility and trouble and took up exactly the same space in any dock or harbour. A Clyde firm had once designed a ship with a net register tonnage of a minus quantity. To this very day there were tugs on the Thames that had a net register tonnage of nil.

Mr. Hopperton's formula for charging dues on the length of the quay that a ship occupied and the depth of the ship was in effect charging on displacement; in other words, it was just a matter of the actual water which the ship was occupying. A more equitable basis would be to charge the actual displacement—not the loaded displacement—which could quite easily be obtained from the displacement scale in the vessel's chart-room after the draught of the ship had been ascertained.

He had been struck by the author's statement that American ships did not include their upper structural work—their cabins—in the net register tonnage. He thought that was wrong from a dock point of view, because the greater the height of the ships the more expensive and difficult they were to handle in a dock. There were many passenger ships with very high decks. He did not think they had ever supplied themselves with a derrick to discharge their own heavy lifts, and a port often had to supply a floating crane of a great size which could never be expected to pay its way; it became a facility. Then, again, ships were becoming larger and tugs had to be more powerful in order to deal with them. More men were required to handle them if

Harbour Accommodation—continued

they came through a lock; they were considerably more expensive from a dock point of view. There was often the case of a ship being built with 2 or 3-ft. additional beam only, but it meant an entirely new entrance being built at a dock at the cost of perhaps a million pounds. The trouble was that the net register tonnage of these vessels did not increase by anything appreciable; in fact in some cases it had been decreased.

Net register tonnage, far from being a good basis for applying charges, was very uncertain. Perhaps he could best stress that point by mentioning the old turret ships which had been built for the Suel Canal years ago. They had been built definitely for the purpose of evading charges, and what had happened had been that the Suez Canal authorities had had to alter their system of charging in order to overcome that difficulty when they found that more turret ships were being built.

As a junior member he endorsed the submission made by Mr. Hopperton in the last paragraph of his paper.

The Chairman, in closing the discussion, referring to the author's statement that the great majority of ports had been long established, charters as old as 1805 being held, pointed out as a matter of history that Bristol had begun with a charter from King John and that Liverpool also had some very old charters, certainly Stuart ones. He remembered reading in the history books about some trouble with Charles I. over some of the dock dues at the small port, as it then was, of Liverpool which he had sold to somebody and over which they had a law suit. He believed there were a good many other cases of very old charters from the Crown. But that was a minor point in a very interesting paper. He agreed thoroughly with Mr. Hopperton on the question of the basis of dock dues. Everybody who had anything to do with charging dues in docks admitted, he thought, that the net register ton was a most unsatisfactory and difficult standard. Various suggestions had been made from time to time to alter it but the problem had not yet been solved. It was particularly hard on the smaller shipowner. The port authority was obliged to arrange its scale of charges so as to cover its working expenses and its interest on capital. The great increase in the depth of ships in recent years had forced many harbour authorities to dredge and deepen their harbours. That was a very expensive operation and it was for the benefit of a very small percentage of the total shipping using the port; yet, under the present system of charging, those ships paid no more in proportion than the ships of much lighter draught. The suggestion had been thrown out that a scale based on draught—so much a net register ton, say up to 20-ft., so much more for a ship between 20 and 30-ft. and so much more again for ships between 30 and 35-ft.—would be a more equitable arrangement. It was a problem that urgently needed settlement and the longer it remained unsolved the more difficult it would become.

He had consistently preached the necessity for a better standardisation of charges. That did not mean that the charges were to be the same everywhere, but they might be on the same basis. Both in regard to the actual schedules of charges and to the accounts of a port (for it was necessarily the expenses which fixed the charges and there was no ready means of comparing one port with another) the situation was very confusing, especially to foreign owners. Railway companies had a standard form of account and a standard form of charges, and anybody could ascertain exactly what he would have to pay for a ton of a given kind of traffic from any one point to another point. The foreign shipowner had no means of obtaining similar information and had to fall back on an English agent who, in his turn, had to make enquiries by correspondence from every port which he thought might form a suitable route for the goods. Some of the coast lines had already met that difficulty by issuing tariffs including the land transport and sea transport from point to point. He remembered also that before the war some of the American lines had issued rate lists, which the exporter could obtain at any time, showing the total charge—rail, steamer, labourage, and so on—from any point in the middle of Canada to any point in the interior of the United Kingdom. But all that seemed to have passed. No doubt the shipowner knew it and was able to tell his own customers, but it would be a great advantage if it was made available to the public in the same way that railway rates were made available.

Another point on which he thought there would be much agreement with the author was the question of the time factor—the period which was to be covered by the due. That was very largely met, because most port authorities did quote a much lower due per net register ton for certain trades for occupation for a shorter period—a week or ten days or a fortnight as the case might be. At the same time he agreed that 30 days was now an unnecessary long time. But to alter this meant recourse to legislation. The problem of the despatch and the time occupied was one in which the port authority was helpless. It was really a matter of the terms of the charter party between the merchant and the shipowner. It was heartbreaking to see a ship deliberately slowed down and discharging at half capacity, perhaps with other ships waiting to berth, because the merchant had so many days to take away the cargo and it did not suit him to move it any faster.

The author had said that roughly the charges were divided equally between the ship and the merchant but there were many exceptions. He noticed that Mr. Hopperton throughout his paper had not used that term which was so well known—" the custom of the port." Where the same kind of cargo was handled out of exactly the same kind of ship, at different ports the incidence of charges between shipowner and merchant was completely different. This caused considerable friction and it would be a great relief if uniformity could be obtained.

In Appendix 2 the author gave the quayage, and worked out the revenue per day per foot of quayage. Perhaps in his reply he would state how he measured that quayage, because every port had more or less dead quay space which really was not a workable space. Sometimes there was a length of quay where the water had shoaled up and a ship could not be got alongside of it. He himself had tried in the past to secure a standard measurement of working quay from which could be deduced the earnings per foot.

The Author's Reply

Mr. H. Hopperton, in replying to the discussion, said that so far as dock signals were concerned, each harbour authority went its own way subject to consultation with the district lighting commission. There were the Irish Lights Commission, the Northern Lights Commission, and Trinity House for England, but he thought each harbour authority could do as it liked. In his paper he suggested that there should be some codification of the signals for entering and leaving harbour and other indications.

Mr. Salt had referred to the differentiation between " coastwise " and " foreign." When he used the term " coastwise " he meant actually the ships passing up and down the coast of Great Britain He would call the other trades he had mentioned " short sea trades "—for instance, a ship going from Hull to Antwerp. He made the three classifications—the coasting trade, the short sea trade and the foreign trade; and each of those was sub-divided into regular and irregular shipping.

Respecting the provision of cranage, he could show Mr. Salt a 30-ton electric crane built in 1918 for a specific shipping company at their urgent request, yet that shipping company had never contributed a penny towards the crane's capital cost of £7,000 nor shipped a ton of traffic with it.

He was glad Mr. Salt agreed with him on the time factor; it was a most important point.

Mr. Hannay-Thompson had stressed the fact that the statutory basis was not the actual basis. There were so many exceptions to the rule that the exceptions condemned the basis. He had been interested to hear about the privately-owned harbour which Mr. Hannay-Thompson had mentioned. He (the author) thought he had run the whole gamut of systems of management, but he had never had the pleasure of managing a privately-owned harbour. He took it that the harbour had some statutory power.

Mr. Course had very aptly described what he himself had been trying to prove, namely, that this tonnage question was an exceedingly complicated one. He had tried to avoid further complication by omitting all reference to loadline. He thought that what Mr. Course had said proved that net register tonnage was not a ton; often it was not a measure. Our yard measure and weights were most carefully standardised. The standard yard measure was a piece of bronze which could not move or expand, and it was kept in an air-tight case at a certain temperature. Yet the port authorities were dealing with 208,000,000 tons which did not mean anything more than " a piece of string."

It had been suggested by Mr. Course that displacement would be a better basis. He (the author) had refrained from being dogmatic respecting an alternative to the net register ton.

The turret ship still existed, but he thought the port authorities were getting a reasonable measurement. The basis had been altered to meet the new kind of ship. That, again, was another admission that the basis of charging was liable to all sorts of expedients—of shelter decks, and so on.

The Chairman had asked him to state something about the " custom of the port." In his experience the custom of the port was a very variable quantity. It varied in nearly every port in Great Britain. In the paper he had given two examples. The custom in the iron ore trade (which incidentally had been determined by a shipowner who was still alive) was for the shipowner to pay the cargo dues. The steel trade on the other hand had adopted an absolutely opposite custom in so far as it undertook the loading and discharging of the ship, which was really a shipowner's job.

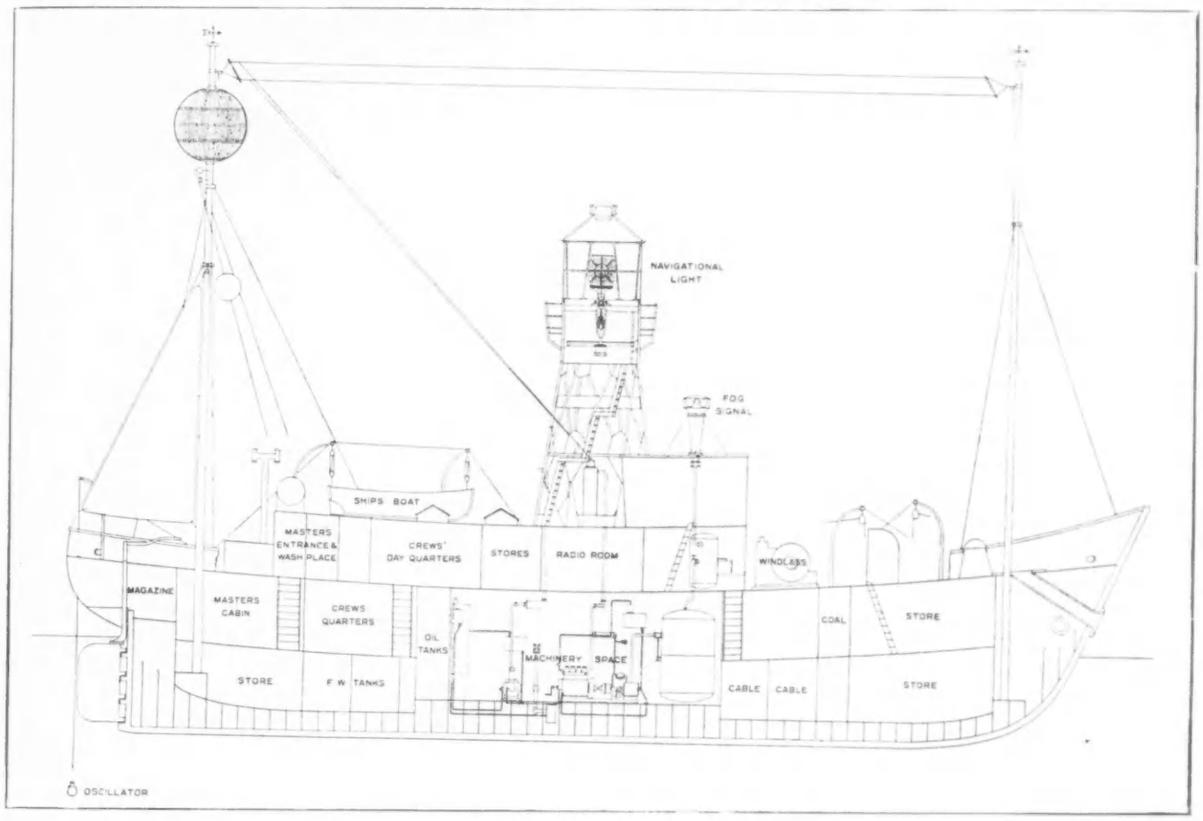
In his measurement of quayage, he had taken the measurement to mean the live usable quayage of berthage. He had left out of calculation such things as quay walls used as approaches, or breakwaters or entrances.

The New Trinity House Lightvessels

(COMMUNICATED)

The Corporation of Trinity House have recently constructed three new lightvessels to replace old lightships; they have been placed respectively at the "Tongue" in the Thames Estuary, "Royal Sovereign" in the English Channel and "Breaksea" in the Bristol Channel. Three further lightvessels of the same type are now in building.

The principal dimensions of the hulls are: Length B.P. 104-ft.; breadth moulded 26-ft.; depth moulded 15-ft.; draught (mean) 10-ft. 9½-in.; displacement 486 tons.



"90" Class Lightvessel

The vessels are built of ordinary mild steel plates and sections and mild steel rivets.

Each vessel has a cruiser stern with ordinary rectangular rudder carried on large mild steel pintles rotating in cast iron bushes.

The stem has a long rake and is an extension of the bar keel up to the steel casting, which has an aperture to take the central riding hawse pipe. The top part of the stem is plate and secured to the hawse pipe casting. The centre riding pipe is cast steel and concentric, so that it can be rotated in the casting when wear takes place. The side hawse pipes are cast iron.

The cable is:—Centre Riding Cable: 210 fathoms 1⅝-in. stud link "Tayco." Spare Cable: Port—150 fathoms 1½-in. open link. Starboard—150 fathoms 1½-in. open link.

The mooring anchor is either a three-ton mushroom or a three-ton Martin anchor with stock. The spare anchors are 25 and 20 cwts. Taylor's Dreadnought, and are carried on billboard recesses.

The riding cable passes from the top of the hawse pipe to the windlass over a large sheave mounted on guides, which is suspended on each side on "Monarch" Shock Absorbers.

The windlass has three gypsies, and is operated by hand or by a 35-B.H.P. Reavall Air Turbine.

The ship is divided by six watertight bulkheads into seven compartments:—Fore peak; store compartment; cable room; engine room; crew space; master's cabin; magazine.

The cable room is arranged so that in an emergency either spare anchor can be let go instantly by releasing the anchor from the anchor recesses.

Storage space for 4,100 gallons of fuel oil for the Diesel engines is provided in built-in tanks between the engine room and crew space. Twelve tons of water is carried in deep built-in tanks under the crew space.

The crew are accommodated in double-tier cots, and have a separate mess room in the deck house. The master's cabin has two fixed berths and two emergency berths. The deck is sheathed over the accommodation with teak. Two muzzle-loading 4½-in. bore guns are fitted on the after-deck.

The deck house is steel, and is divided into spaces for the windlass engine, stores, radio beacon apparatus, galley, crew's mess-room, crew's wash place and water-closet.

A hand Downton Pump is fitted and connected to a single bilge line with cock-controlled branches to the various bilges. This pump is also used to fill the sanitary tank.

The deck-house top acts as boat deck, and accommodates two 16-ft. class 1.A lifeboats under swing davits.

A steering shelter and lookout is fitted at the fore-end of deck house, and the after-end of this space is worked into the base of the lantern tower, which is a lantern structure built with angles and plate stays.

Two tubular steel masts, 64-ft. high above water line, are fitted to take the wireless and radio beacon aerials.

The mizzen mast is used to carry a signal yard and stay sail. Both masts can, if necessary, carry top-marks.

The vessels are lighted throughout by electricity and are equipped as to navigational aids with a powerful electric light, a diaphone aerial fog signal and an oscillator submarine fog signal. The "Breaksea" is also provided with a radio-beacon, and the "Tongue" has a wireless telephone.

The electric current, both for general lighting and the navigational light, is supplied from 5½ kilowatt generators direct coupled to Gardner 9½-h.p. cold-starting solid injection heavy fuel oil engines. The plant is triplicated to give alternate running and an emergency spare; the generators are arranged for running in parallel if required, and battery and battery charging arrangements are provided where necessary. The supply is 100 volts direct current.

The lanterns are 8-ft. 3-in. diameter, inside the glazing, with a daylight height of 6-ft. 0-in.; the glazing panes are trapezoidal curved to the radius of the lantern and set in gunmetal inclined helical, bar frames with "Stopstara" putty. The roof is galvanised sheet iron on galvanised steel framing, and ventilation is provided through a shielded air duct at the base of the lantern glazing and a copper ventilator on the roof. Galleries and platforms are fitted for cleaning and maintenance purposes.

The lighting apparatus for the navigation light is of the revolving flashing type to produce concentrated rotating beams of light, but each is of different design.

The "Tongue" lightvessel is provided with a dioptric apparatus with segmental panels arranged to show three white flashes in quick succession every 20 seconds; it is so constructed that by the addition of the necessary optical panels the apparatus can be rearranged to show one to four flashes. The illuminant is a 2½ kilowatt lamp with circular zigzag filament in two halves in parallel so that a partial light may be maintained if one leg of the filament fractured.

The Trinity House Lightvessels—continued

The " Breaksea " lightvessel is fitted with a biform catoptric apparatus, comprising two tiers of three silvered glass segmental mirrors of 375 m/m focal length set as 120° apart horizontally around a common focus. The two illuminants are each 1,250 watt lamps with bunched zigzag horseshoe filaments, the light being thus maintained at half power by one tier if the filament in the other tier fails. This apparatus shows only a single flashing light.

The vessel at the " Royal Sovereign " is fitted with a multi-catoptric apparatus, consisting of eight paraboloidal mirrors 18-in. diameter and 6-in. focal length, arranged in two tiers of four vertically super-imposed; each vertical pair is mounted on a common axis so that the mirrors can be angled to produce any character from one to four flashes. Each mirror has in its focus a 375-watt lamp with bunched horseshoe zig-zag filament; over the lamps can be placed a selenium ruby cylinder to give a red colour to the light if required. The apparatus is designed in this manner so that the light character can be readily changed to enable the vessel to act as a spare.

The beam intensity of the three lights is respectively 700,000, 500,000 and 450,000 English standard candles.

In each case the apparatus is mounted on a ball-bearing carriage, rotating on a spindle, which is supported in heavy gimbal blocks and counter-balanced with a pendulum swing of 7½ seconds per semi-oscillation to maintain the apparatus and beams horizontal when there is motion of the vessel. The rotation of the apparatus is effected by an electric motor running at 1,000 r.p.m., coupled to a spur reduction gear to give the appropriate final speed for the optic.

The fog signal machinery consists of a pair of " Gardner " 4L2 engines of 38 h.p., each directly coupled to a 5½ kilowatt D.C. generator of the same type as the lighting plants, and indirectly coupled through V-rope belting to a " Reavell " Q.R. 7½ by 5 compressor, the coupling is made by means of a clutch controlled by a hand-wheel, and is engaged when the engine has been started up. The generator supplies power at 100 volts D.C. for the submarine oscillator and radio beacon motors, and also for battery charging when required. The compressor delivers 175 cu. ft. of air per minute against a pressure of 45 lbs. for sounding the diaphone and operating the winch. The plants are duplicated as stand-by to each other. Fresh water is used throughout for the engine-cooling circulation system, and sea-water for the compressors.

The aerial fog signal equipment consists of a " Chance " G diaphone, consuming 23 cu. ft. of free air per second of blast, the air delivered by the compressor being stored in three air receivers 5-ft. 7½-in. diameter and 10-ft. 3-in. long, whence it is passed through reducing valves to two subsidiary receivers to provide air at a pressure of 35 lbs. per sq. in. for driving the diaphone piston and for producing the sound. The diaphone sounds a note with a pitch of 180 vibrations per second.

The submarine signal is a " Submarine Signalling Company" non-polarised double diaphragm emitter operating on a frequency of 525 cycles per second and sounding a note double this pitch. The oscillator is chain-suspended from a davit near the stern of the vessel in a depth of approximately 25-ft., and is hoisted on board when not in use. The A.C. power is derived from a motor generator run off the mains supply, and the whole equipment is duplicated for alternate running.

The radio-beacon equipment comprises a " Marconi " W.B 6 radio-beacon transmitter with the necessary H.T. and L.T. generator unit and associated electrical apparatus, normally generating modulated continuous waves, but capable of continuous wave transmission. It can operate on any radio-frequency within the radio-beacon band of 290 to 320 kilocycles per second. The transmitted frequency is crystal-controlled for frequency stabilisation, but the transmitter is so designed that the crystal drive can be cut out and valve drive resorted to without altering the transmitted frequency in the event of failure of the crystal by means of a single switch. There are two main magnifiers, and the output power can be reduced by utilising one only. The aerial is of the L type, with the roof spanned between the two masts and the down-leads brought from the mizzen end to the centre of the vessel on either side of the lantern trestle whence they are led to a lead-in trunk over the radio room. Indicating devices are fitted to show that the signals are being transmitted, and alarm gongs sound should there be no radiation from the aerial. The equipment is duplicated, as elsewhere, with an aerial change-over switch to link the aerial to either transmitter.

The emissions of all three fog signals, that is diaphone, submarine oscillator and radio-beacon, are electrically controlled from a central code-sender of Trinity House pattern, also duplicated and provided with cams and contact triggers and driven by a motor fitted with a "Creed" governor speed control. The code-sender is of the self-operating type when once started up, and has a six-minute running period. The restarting is effected by a time switch regulated to Greenwich mean time so that the code-sender also functions with the same regularity; this is essential to avoid the overlapping of the radio-beacon transmissions with other radio-beacons around the coast.

A Trinity House Lightvessel

The radio-beacon signals are synchronised with the submarine signals to provide a distance-finding service as well as a directional service.

Investigations into Structural Stability

Two matters of essential interest to dock and harbour engineers are to be found in the summary of the Report of the Building Research Board which, with the Report of the Director of Building Research for the year 1937, has been published by H.M. Stationery Office (3s. 6d. net). The Report lays special stress on the importance of recent developments in soil mechanics and the two matters in question, viz.: settlement of structures and stability of earth slopes, intimately connected as they are with the design of quay problems, are problems, the elucidation of which depends upon research in this subject. In the past, it is pointed out that questions of foundations and earth slopes have had to be dealt with on an empirical basis on account of the lack of scientific knowledge.

An outline is given of the method used in estimating and analysing the settlement of a structure. It is based upon the laboratory examination of soil samples taken in an " undisturbed " condition from various strata beneath the structure. The apparatus used is known as the Terzaghi Oedometer, and from the results of these tests, together with a calculation of the distribution of pressure from the building in the subsoil, it is possible to estimate the amount of settlement to be expected.

As regards the stability of earth slopes, there has been a tendency in the past to consider that the safe angle at which an earth slope can be constructed depends only on the type of soil. While this is approximately true for essentially granular soils, the idea has to be modified considerably, so far as clay soils are concerned. The Report points out that the stability of an earth slope depends upon the shear characteristics of the soil in the slope and in the foundation layers. The shear resistance of clay depends essentially on its cohesion, and, in consequence, the maximum angle at which a clay slope can stand without support decreases rapidly with increasing height. In addition, the influence of adverse weather conditions must also be taken into account. Experience shows that slides in clay slopes take place along surfaces which have a conspicuous curvature, approximating to a cylindrical form. Methods are described in the Report, which have been developed for the analysis of the stability of slopes on the basis of the equilibrium of a segment by such a cylindrical surface.

*Canal Locks and other Lifting Devices in Inland Navigations**

By D. G. McGAREY

Introduction

IN railway or road construction the surface upon which the moving vehicles travel can be made to follow more or less closely the undulations of the ground, and gradients of varying severity may be introduced wherever and as often as required without interrupting its continuity. In the design of inland waterways, however, it is impossible to do this, and a horizontal line is the only form which a longitudinal section of a canal can assume without obstruction, and if, owing to the requirements of the line of route, a change of level becomes necessary it means that an ascent or descent from such a level stretch must be made abruptly by means of some lifting and lowering device, of which the lock is, of course, a familiar example. The object of this paper is to describe in outline the problems met with in the design of these lifting devices and the considerations which govern their application to the varying conditions obtaining on the different classes of waterway. Locks, such as those used at the entrances to tidal basins, docks, and in connection with maritime navigation generally, comprise another aspect of the subject which it is not proposed to touch upon.

River Navigations

A brief survey of the historical side of the problem will show how the necessity for locks or other similar appliances first presented itself, and without going into great detail, it will be sufficient to say that the need was first felt in connection with the navigation of rivers, which were practically the only reliable means of transport for goods during the Middle Ages and up to at least the end of the seventeenth century. But rivers were only useful as far as they *were* navigable, and on each one there was some point above which it was normally impossible to take a boat of reasonable size. This point might vary with the season, and in times of flood places could often be reached which otherwise were too far upstream. Such places, having once felt the advantages of a navigable stream close at hand were not likely to tolerate indefinitely the inconvenience of being left literally "high and dry," if only some means could be devised of overcoming the difficulty, and obviously one solution lay in creating artificial floods by damming up the river at some convenient site downstream.

Staunches and Flashes

This, however, created in turn another difficulty, in that boats would not be able to pass the barrier forming the dam, and thus transhipment of the cargoes at these sites would become necessary with consequent loss of time and money. In many cases the remedy would be worse than the fault and necessity led sooner or later to the invention of Staunches, which consisted essentially of dams or weirs with removable sections, which when closed allowed water to collect and rise over the shallows above, thus making them temporarily navigable, and when removed made an opening for the passage of the boat. It would then be necessary, after the boat had passed through, to replace the staunch and wait until the natural flow of the river had filled up the reach above before the boat could proceed upstream. A system of "flashing" was also often adopted, which was more favourable, however, to downstream traffic than in the reverse direction, and consisted in withdrawing the staunch when a boat had arrived there and letting a flush or "flash" of water flow down which would carry even deeply-laden craft over the shallows below, whereas an upstream boat would be restricted to the draught which could be accommodated on the lower side of the weir before the withdrawal of the staunch.

If the river were so shallow that navigation would otherwise be altogether impossible, then it would be necessary to construct staunches sufficiently close together for the "tailing back" effect of one weir to have a considerable effect at the one next upstream, or in other words, the water would be artificially impounded to form a series of navigable pools or "pounds," boats being lifted from one to the next at each staunch by the methods described above. On the whole, the process was effective, but wasteful both of time and water, and was very restricted in application.

Development of the Lock

With increase in traffic some better and more reliable means became very desirable, and the next stage in the history of lifting devices is marked by the invention of the lock, and here it is interesting to observe that if two staunches were placed close together the natural river flow would quickly fill the intermediate pound once a boat had passed the lower one, so that in a short time it would be able to pass the next staunch also, thus having passed from one main reach to another by means of a subsidiary pound capable of regulation between the two levels. Now in principle this is exactly what a lock consists of, that is to say a chamber, enclosed by movable dams or gates at each end, constructed at a point separating two reaches at different levels, means being provided to pass the water at will from the upper reach into the chamber, or from the chamber to the lower reach, so that the water inside, and therefore any boat floating in the water, can be raised or lowered from one level to the other as required.

The lock appears to have been invented or developed in Italy, having been employed towards the end of the fifteenth century on the Brenta, near Padua, and there are also indications of devices of a similar type having been used in Holland and Germany about the same time. The first example found in this country, however, was on the Exeter Canal, about eighty years later, when the canal, which was originally planned as an artificial channel open to tidal action in 1539, was extended and provided with gates to retain the water at low tide. This lock at the present day comprises two pairs of gates enclosing a length of the canal channel, and no doubt represents the earliest type of lock in the country.

Typical wide (barge) lock on Grand Junction Section, Grand Union Canal

Little appears to have been done, however, to extend the use of such devices until a series of Acts for improving River Navigations began to be passed in the seventeenth and eighteenth centuries, as a consequence of which locks gradually came into general use for making navigable the upper reaches of many of our rivers. The first entirely artificial waterway in this country was the Bridgewater Canal, constructed by James Brindley about 1760, soon followed by many other such undertakings in all parts of the country, and thenceforward the lock became an essential element in the development of Inland Transport. For over three centuries it was the only lifting device in use on inland waterways, and to the present day it has remained the most generally serviceable means for its purpose.

LOCKS

General Description

Now a lock consists essentially of a chamber large enough to hold at least one of the boats using the waterway, and deep enough to extend from the bed level of the lower reach to the bank level of the upper reach, the sides and bottom generally being built of brickwork. At the top end a head-wall is provided across the lower part of the chamber, carried up to the bed level of the upper reach, and upon this is constructed a projecting sill, normally in the shape of a blunt arrow-head pointing upstream. From the points where the sill meets the lock sides grooves, part circular in plan, are carried up to the top of the lock walls, and in these "hollow-quoins," as they are termed, the ends of the gates partially revolve. One, or

* Paper read before the Junior Institution of Engineers on 11th March, 1938.

Canal Locks and other Lifting Devices in Inland Navigations—continued

more usually, two gates are provided here, and when closed across the lock make a watertight seal down the quoins, across the sill and up the meeting edges of the gates. At the lower end of the lock a similar sill and gates are provided, but are built on and up from the invert, the gates thus extending the full height of the lock. Sluices with gear for opening and closing them are provided either in the gates, or in culverts passing round the backs of the hollow-quoins, in order to pass water into and out of the lock chamber as required.

Narrow lock formerly used on Warwicks Section of G.U.C., showing also new wide lock in use alongside

The earliest locks, as already described, consisted merely of a length of canal or river divided off by two pairs of gates, the intervening chamber so formed often having unprotected natural banks, but the continual scour from the sluices soon made it desirable to protect at least the toe of the banks by timber sheeting or masonry, and later it became customary to provide some permanent protection along the whole length of the chamber sides. At the ends, however, the gates were usually set in brickwork or masonry, and eventually the practice was adopted of constructing the whole lock in brickwork as a separate structure to withstand the wear and tear of constant use.

As a result of the somewhat haphazard development of individual navigations and canals, and the failure of their designers to realise the eventual possibilities of linking up all waterways in one system, a feature of the locks in this country is their lack of uniformity in size, or even in the proportions of their dimensions. On rivers and navigations the object of installing locks was mainly to enable the existing vessels to proceed further upstream, so that relatively large locks were necessary. In the earlier types, where they occupied the whole width of the channel, as at Exeter, it was often possible for two or more boats to enter and lie side by side, or a long type might be constructed capable of taking several boats end to end, as some of the Thames locks do to-day, and in later times specially large locks often were constructed to take four or more barges at one operation. In canals, on the other hand, the scale of the whole undertaking would depend on the size of the boats to be used, and as these would generally be specially constructed for use on the particular waterway concerned any financial limitations here always tended to the use of small locks. Important canals, where a large traffic was expected, would construct larger locks, and so each waterway would provide for its own needs, with the proviso, however, that the later canals, built for the purpose of linking up existing ones, would naturally make their locks of a size to match those waterways.

Typical Locks

Canal Locks, in most cases, are made only large enough to take one of the boats or barges using the waterway, owing to the need for economising, as far as possible, not only in first cost but in the amount of water required for each locking operation. The bulk of the locks on English canals are constructed to take either the usual narrow boat averaging about 72-ft. long by 7-ft. beam, with a draught of 3-ft. 6-in., or, on the barge canals, a single barge about 75-ft. long by 14-ft. beam, with a draught of 4-ft. The barge lock will, of course, hold two narrow boats at a time, and in some cases such locks were provided for this purpose even when no barge traffic existed. The advantage of this arrangement is of great benefit on the Grand Union Canal main line between London and Birmingham, where the through traffic is carried by motor boats and dumb or butty boats in pairs, and all the locks on this route are now capable of passing a pair through together, over fifty locks having recently been entirely reconstructed. These locks were originally all of the narrow type, capable of taking only the 7-ft. beam boats using the canal, but are now 83-ft. 6-in. long by 15-ft. wide, and give a depth of 6-ft. on the sills, the ultimate object of the reconstruction being to enable 14-ft. beam barges to travel direct from London to Birmingham. This size has also been adopted in the recent reconstruction of two locks on the River Nene, below Northampton, at which town connection is made with the Grand Union system.

The largest locks on the Grand Union Canal other than the above are found on the Regents Section in London; these are all in duplicate, and can each take 100-ton barges 78-ft. long by 14-ft. 6-in. beam by 4-ft. 6-in. draught.

As an example of modern Continental practice, the large canal locks in Germany are now standardised at 39-ft. 4-in. wide by 9-ft. 9-in. deep, alternative lengths being 328-ft. to take one barge with tug, or 738-ft. to take two barges with tug. These barges are 34-ft. 6-in. beam, and either 213-ft. or 262-ft. in length, so that the longer locks will take three of the smaller barges and a tug if required. At a draught of 8-ft., these craft would have a carrying capacity of about 1,000 to 1,250 tons.

River Navigation Locks are far more variable in size, owing to their having been built, as a rule, to accommodate various existing types of craft, but space forbids the mention of more than one or two examples. On the River Weaver Navigation in Cheshire, the ordinary type of vessel using the river measures 90-ft. by 21-ft., and the locks are constructed to take four of these at a time, being 229-ft. long and 42-ft. 6-in. wide. The normal maximum draught is about 10-ft., although the lock sills are 15-ft. deep to allow for possible future increases after dredging. On the River Thames there are three lock chambers at Teddington, below which the river is tidal, which measures 650-ft. by 25-ft., 177-ft. by 25-ft., and 50-ft. by 6-ft. respectively. Vessels navigating the river are, of course, of every description and size, and it is usually most economical to have the lock chambers of different sizes when more than one is required at any one site. The maximum size of craft capable of navigating the river as far as Oxford, above which very little trade is done, is 120-ft. by 17-ft., with a draught of 4-ft. Craft 120-ft. long by 17-ft. 6-in. wide by 7-ft. 6-in. draught are navigated on the Aire and Calder, the locks being 210-ft. by 18-ft. by 9-ft. in size.

Hampstead Rd. Duplicate Locks, Regents Section, G.U.C.

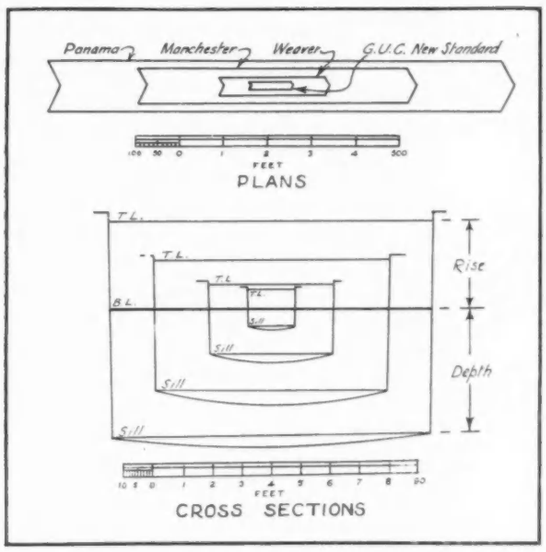
Certain of the locks are 460-ft. long, and are intended to take a complete train of the compartment boats, including tug, which are a feature of this particular waterway. The canalised River Severn, between Gloucester and Worcester, can pass 200-ton vessels 135-ft. long by 22-ft. beam by 9-ft. draught, and even higher up barges 87-ft. by 15-ft. 6-in. by 6-ft. can be navigated.

Actually, locks of all sizes exist, especially on the Continent, up to those which really come within the limits of the next paragraph.

Ship Locks may have a brief mention here, although ship canals cannot strictly be included under the designation of Inland Waterways, and these represent the largest and latest development of the lock. Those on the Caledonian Canal are 170-ft. long, 40-ft. wide, and give a depth of 17-ft. on the sills, while the Manchester Ship Canal has several of different sizes, the largest being 600-ft. long and 80-ft. wide. Others are 600-ft. by 65-ft., being sub-divided by intermediate gates into two chambers respectively 450-ft. and 150-ft. long, and in each case the sill depth is 28-ft. The Panama Canal possesses the largest

Canal Locks and other Lifting Devices in Inland Navigations—continued

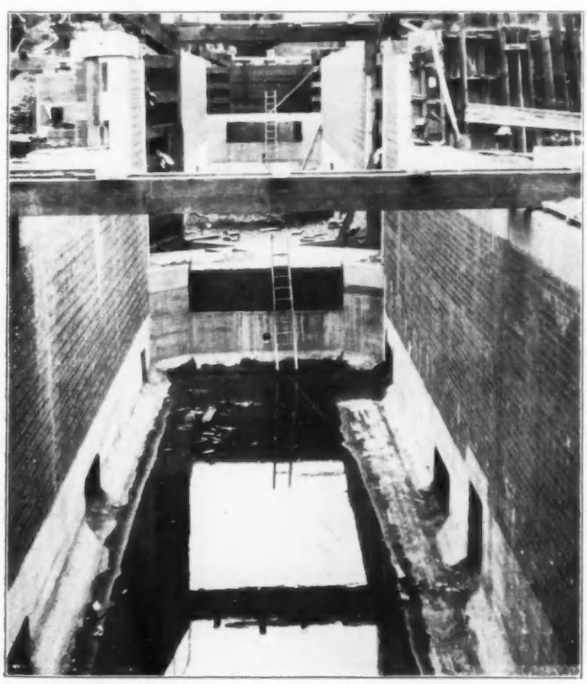
locks ever constructed, and will take the largest ships afloat, with the exception only of the latest ocean liners. These locks



are 1,000-ft. long, 110-ft. wide, and there are six duplicate sets altogether, three at Gatun forming a series with a total difference in level of 85-ft.

Rise of Locks

Generally speaking, the larger the locks, the greater rise they are given, but for canal locks the normal rise or lift varies between 4-ft. and 10-ft., about 7-ft. being a very usual figure for English canals. On the Continent larger rises are usual, the Scheldt-Meuse Canal—a typical example of a modern Continental canal—having locks with a rise of 13-ft. The Manchester Ship Canal employs a figure of about 16-ft. 6-in., and on the Panama Canal the average rise is 28-ft., the maximum ever occurring under the most adverse tidal conditions being 39-ft. Large rises mean fewer locks for a given total difference in level, and thus tend to save time, but, on the other hand, entail a greater expenditure of water, and in the case of canalised rivers a considerably greater amount of work in raising the banks or dredging the bed. Another disadvantage is that the lower gates require to be of very heavy construction

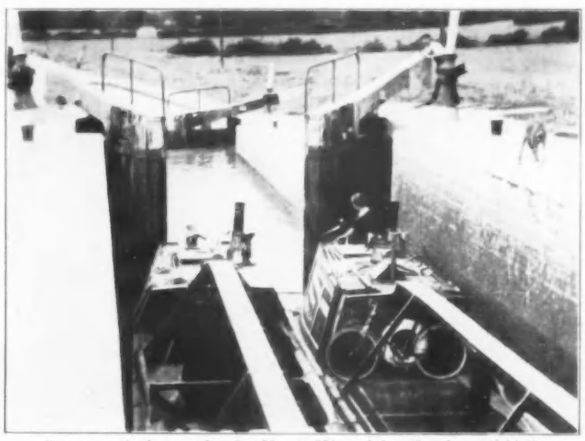


Bascote Staircase Lock under construction, showing also culvert openings into chamber from sluices and side ponds

as the depth is increased, although the difficulty was first overcome in a French lock, with a rise of 32-ft. 6-in., by carrying the gate up only to a clearance height above the lock tail, an arch being built over between the sides and carried up to the top as a solid end to the chamber. This type is known as a shaft lock, and by its use the practicable rise has been considerably increased in recent years, so that in Germany dimensions of 50-ft. and upwards have been employed with success. These entail special treatment and modifications, however, which will be discussed later.

The rises adopted on the Grand Union Canal for the new locks previously mentioned vary between 5-ft. $5\frac{3}{8}$-in. and 8-ft. $4\frac{1}{2}$-in., being governed to a large extent by existing pound levels, but the opportunity was taken to standardise the rises of all locks in any particular flight by splitting up the total rise equally between them. The longest flight is at Hatton, near Warwick, and comprises twenty-one locks overcoming a total difference in level of 146-ft. 6-in.; the average gradient is 1 in 72 over a total distance of two miles. Other long flights in this country occur at Wigan, on the Leeds and Liverpool Canal, with a similar number of locks, the difference in level being 199-ft. 6-in., at Devizes on the Kennet and Avon Canal, having twenty-nine locks, and at Tardebrigge on the Worcester and Birmingham Canal, where thirty locks are employed to surmount a total rise of 203-ft. This flight contains the greatest number of locks of any flight, and the top lock has the greatest rise of any single boat or barge lock, in this country, being no less than 14-ft.

Occasionally, what are known as "Staircase" locks are met with, in which a series of lock chambers is constructed in tandem, the lower gates of one chamber forming the upper gates of the one below, and so on. The object of this is to obtain the maximum gradient possible in a flight of locks, and the advantages and disadvantages attaching to this modification will be discussed later.



Bascote Staircase Lock (New) Warwicks Section, G.U.C.

Locks for other Purposes

Two other types of lock sometimes found on canals are the Stop Lock and the Shallow Lock, both of which are constructed at the junctions of two canals, or of different branches of the same canal, for the purpose of maintaining the level in one branch should the water in the other fluctuate or be drawn off.

Stop Locks are provided as a means of shutting off one branch altogether, but give free access between the two branches when they are at the same level, and usually comprise a normal lock chamber fitted, however, with two pairs of gates at each end, one pair at each end facing one way and the other pairs the opposite way, all gates normally being kept open to allow free passage for craft. The water in either branch can, therefore, be raised or lowered independently of the other if and as required by bringing into operation the appropriate pairs of gates and working as an ordinary lock. Such locks are sometimes found at the junction of tidal and non-tidal waterways, and are then called "Reversible Locks."

Shallow Locks are similar in all respects to normal single chambered locks, but have a rise of a few inches only, the object being to provide a non-return valve so that the canal at the lower level will never have to supply water to the other. With Stop Locks, which are normally kept open, there is no guarantee that this will be so, and in the case of a canal suffering from limited natural water supplies it would be a normal condition that any other canal subsequently making connection with it should never abstract any water for its own requirements, the construction of a shallow lock near the junction being very often insisted upon as a means of ensuring the fulfilment of this condition.

Limitations of Locks

In river navigations locks are usually constructed either where the river divides into two channels, a lock being built in one branch and a weir in the other, or an artificial channel is cut across a neck or bend to contain the lock and to provide a short cut, a weir then being constructed across the natural

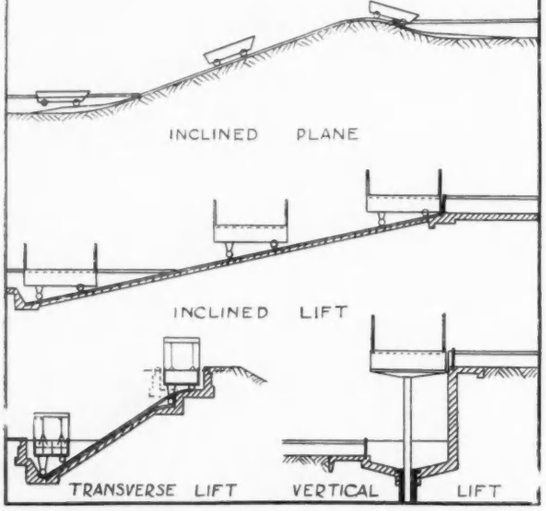
Canal Locks and other Lifting Devices in Inland Navigations—continued

channel. The question of the best location for locks, however, does not strictly come within the province of this paper, but in the case of arterial canals, that is to say, artificial waterways constructed so as to run also over the higher ground forming watersheds between two river basins, the problem assumes another complexion, for as the route leaves the easier gradients of the valley and becomes steeper, then the locks must succeed one another at closer intervals. In many cases the summit over the ridge is reached without very steep slopes being encountered, or a tunnel may be used to avoid the final rise, but in other cases, and also sometimes at other points on the route, steep and lengthy flights of locks may be necessary to overcome some particularly awkward rise in the route profile.

Now there are many disadvantages in constructing and navigating a flight of locks placed close together, not the least important being the increased time taken in passing through; while it is in the higher ground that difficulties arise in ensuring that adequate supplies of water are available under all conditions. The mean gradient of a flight depends on the rise and on the distance apart of the individual locks, and the latter must be sufficient not only to provide passing places for boats but to provide pound areas large enough to avoid undue fluctuations in the water level owing to the varying demands of the locks. The minimum desirable distance apart is about 300 yds., which therefore allows a maximum gradient of about 1 in 100 using a rise of 9-ft. If, to give a steeper gradient, the locks must be placed closer together, then the pounds should be widened in compensation, and this tends to be an expensive procedure; in any case, there must be a limit to this shortening of the pounds as passing room is necessary, and a slope of 1 in 30 is about the steepest obtainable with this modification. Still greater slopes up to about 1 in 10 can be obtained by the use of staircase flights, but it is impossible for full-sized craft to pass one another, and they are not economical of water, as there are no intermediate pounds to act as reservoirs in case of irregular traffic, so that they are only practicable for total lifts of about 30-ft. or so. Steep slopes, especially long ones, therefore require special treatment, and unless the construction of locks with exceptional rises is contemplated, some form of alternative device must be adopted.

CANAL LIFTS
General Description

Leaving aside for the moment the possibilities and problems connected with very deep locks, there are three principal alternatives, which may be designated as Inclined Planes, Inclined



Lifts, and Vertical Lifts, involving in each case the bodily raising of the boat, either directly or by means of a carrier, from the lower to the higher reach by mechanical power.

Inclined Planes consist merely of lengths of railed track laid on a gradient between the two reaches of the canal, the boats either being fitted with wheels or are carried directly on a wheeled carriage running on these rails. The motive power is supplied by means of a capstan and rope, or two parallel tracks may be used for ascent and descent respectively, the boats being counterbalanced in trains or in pairs. Generally speaking, Inclined Planes are only suitable for small boats, as there is a danger of larger ones becoming strained if they are not continually waterborne.

Inclined Lifts differ from Inclined Planes in that the boat is carried in a horizontal tank of water, which in turn is supported on wheels running on inclined tracks. Here, again, two counterbalanced tanks may be used, and in this case an exact balance can always be obtained between the two tanks as the combined weight of a tank and barge is independent of the load in the barge, and thus a considerable reduction in the amount of motive power is obtained while doubling the capacity of the lift. Inclined lifts are most suitable where long gradients of about 1 in 12 to 1 in 4 have to be surmounted, or where such a slope can be constructed easily without excessive excavation or forming of embankments.

Vertical Lifts frequently consist of a tank supported and actuated by hydraulic rams or wire ropes carried over a system of pulleys, the tank moving vertically between guides, although there are many other systems in use. As in the former case, the ends of the tank are closed by gates which can be raised to admit of the entrance or exit of the boat before and after lifting, and where a similar gate is provided at the adjoining end of the canal pool, the two gates may be lifted together by a single hoist, automatic locking arrangements coming into action as they come into contact at the end of the lift movement. Vertical lifts are advantageous where a single abrupt ascent of considerable amount has to be made, or where space is definitely restricted—as in the case of a connection to be made between two existing waterways close together but at different levels. Counterbalanced pairs of tanks are sometimes used in vertical lifts also. One or two examples of each of these types will now be described briefly.

Inclined Planes

The Bude Canal, in Cornwall, was constructed with short inclined planes in place of locks, the tub boats then used, about 20-ft. long by 5-ft. 6-in. beam by 2-ft. 8-in. draft, being equipped with wheels for the purpose. A little later two inclines, of the same type, but considerably longer, were constructed in Shropshire where boats of similar size were in use. In one case the total rise was 213-ft. on a grade of 1 in 4, in the other 73-ft. 6-in. on a grade of 1 in 9, and in both examples there were two tracks and two counterbalanced cradles connected by wire ropes. In a similar case in America, twenty-three inclines on gradients of from 1 in 10 to 1 in 12 were introduced, the barges, carrying 70 tons, being carried on eight-wheeled cradles running on a 12-ft. 4-in. gauge track. Other instances occurred on the Continent, but the type generally began to be dropped in favour of the inclined lift about the middle of the nineteenth century.

Inclined Lifts

About 1840 an inclined lift was constructed on the Chard Canal in Somerset, working on a gradient of 1 in 8, double counterbalanced tanks, 28-ft. 6-in. long and 6-ft. 9-in. wide, being employed. Near Glasgow the Monkland Inclined Lift was constructed about the same time, a similar arrangement being used on a rise of 96-ft., with a gradient of 1 in 10 to replace a flight of eight locks. The gauge of the track was 7-ft., and the tanks were 70-ft. long, 13-ft. 4-in. wide and 2-ft. 9-in. deep, each carried on twenty wheels. A later example near Washington, in America, was the Georgetown Inclined Lift, constructed in 1876, in which a single tank 112-ft. by 16-ft. 9-in. by 7-ft. 10-in., carried on three trucks, was counterbalanced by stone-laden wagons running on parallel tracks on each side of the main track.

(To be continued).

Port of London Staff Appointments.

The Port of London Authority have appointed Mr. John Douglas Ritchie, M.C., to be General Manager of the undertaking as from the 30th September next in succession to Sir David J. Owen who retires on pension on that date. Mr. Ritchie entered the service of the Port Authority as Solicitor in 1923; in 1927 he was appointed to the joint office of Solicitor and Secretary, and he has been Deputy General Manager since the 1st January last.

The following appointments have also been made:—Chief Assistant to the General Manager: Mr. R. Letch (formerly Assistant Dock and Traffic Manager); Assistant Dock and Traffic Manager: Mr. E. H. Lennard (formerly Stores Officer); Stores Officer: Mr. E. L. Stanley (formerly Personal Assistant to the General Manager).

Precautions against Air Attack.

The Institution of Civil Engineers, with the approval and collaboration of the Air Raid Precautions Department, have appointed a Committee for the compilation and publication of authoritative technical information on the subject of precautions against air attack for the use of engineers in their work of design, construction and maintenance of structures and other engineering work, including public utility services. This Committee which, under the Chairmanship of the President of The Institution, consists of engineers conversant with both the practical and scientific aspects of the subject, has been promised by the Air Raid Precautions Department all possible assistance in the form of available scientific data concerning the problem.

The Yangtse Estuary

By HERBERT CHATLEY, D.Sc. (Engineering), M.Inst.C.E.

General

THE sea approach to Shanghai and Central China is through the estuary of one of the world's great rivers, the Yangtse, which rises in N.E. Tibet. That river has a catchment area of about 750,000 square statute miles, and, after traversing more than 3,000 miles, it enters the sea at the eastern edge of the main China coast. Bringing down each year a tremendous volume of silt, perhaps 500 million cubic yards, it has built a large delta (some 20,000 square statute miles), which is still steadily growing. As is always the case in deltas, there are several channels, separated by shoals which grow and shift. The ordinary spring tide low-water depth on the bars in the principal channels does not naturally exceed about 20-ft., and is often less than this.

Outside the delta there is a broad continental shelf with comparatively shallow water, over which there is a tide of about 12-ft. range at ordinary spring tides, diminishing to 5-ft. range at ordinary neaps. The tidal wave swings round anti-clockwise in approaching the shore and the tidal currents are rotary. Within the channels, the current paths are long ellipses; the maximum velocity at certain places may be as great as 6 knots (say 10-ft. per second) at spring tides. The water is cafe-au-lait in colour with suspended material, changing from opal green at the oscillating margin of the fresh water. There are no hills on the flat shores visible from the sea, but there are some rocky islands outside. The winds are generally easterly. Occasional typhoons in the late summer, strong winter winds from the north, and a certain amount of fog increase the difficulties of approach.

Shipping

Half the foreign trade of China (or value of about £100 millions in 1936) passes through the Port of Shanghai, and, in addition, in the summer there are ocean ships plying up the Yangtse to Hankow (600 miles up river) so that the largest ships cruising the Indian and Pacific Oceans need to enter the estuary. The " Empress of Britain " is the largest ship which has crossed the bar, but there are other ships of greater draft, approaching about 33-ft. As the spring tide "rise" above spring low water rarely exceeds 13-ft., and the main bar is about 20-ft. deep at spring low water, this figure is practically the limiting draft, and such a ship might be unable to cross again for two weeks.

The annual volume of ocean shipping across the bar is about 15 million net register tons each way. The annual tonnage of cargo is about five million tons each way.

Since the adverse currents may reach 6 knots, ship speeds need to be at the very least 8 knots.

Large numbers of sea-going junks (cargo and fishing) may be met in the estuary.

Aids to Navigation

The Chinese Maritime Customs has developed an elaborate system of lights, fog-horns and wireless signals, and there is an officially-controlled pilotage system.

The lights consist of Pintch buoys laid along the principal routes some 5 miles apart, with manned lightships at important points, and lighthouses and wireless beacons in the islands outside the estuary.

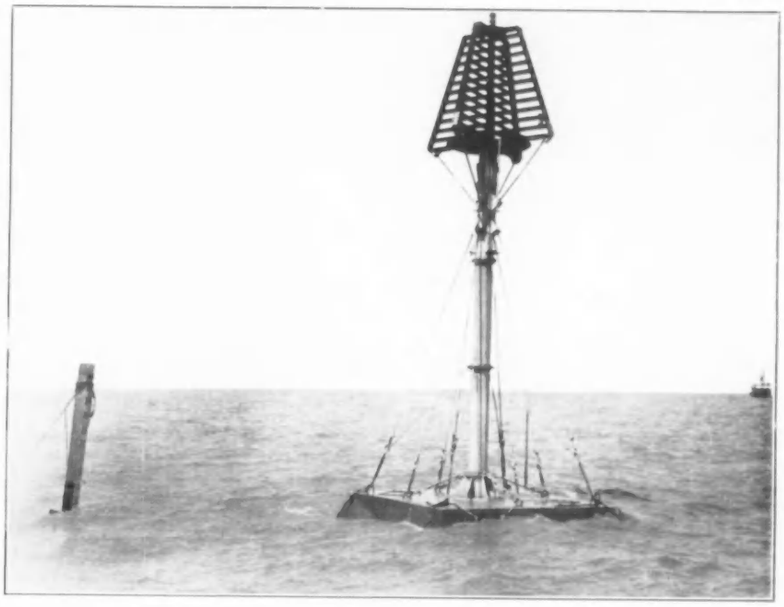
A pilot ship lays just outside the main bar and is in wireless communication with ships and with Shanghai. The pilots, who are all ex-masters with long experience of the bar, estimate the rise of tide and the strength and direction of the currents, and take the ships across at such time as seems best, the commanders themselves having brought the ships to the bar at what appears to be a suitable time according to tide tables published in Shanghai. On the outward voyage the pilot joins at Shanghai and leaves the ship at the pilot boat.

In spite of all precautions, ships ground occasionally and may be held up for one tide.

Excellent charts of the main shipping route are published by the Hydrographic Department of the Chinese Admiralty.

Measures for Improvement

Way back in the " seventies," at the time when the improvement of the Whangpoo was first under consideration, Mr. J. de Rijke, a Dutch river engineer then working in Japan, made a report on the bar of the Yangtse, which then had less bar depth than it has now. He considered that dredging would be futile, an opinion which having regard to the plant of those days was probably sound, and advocated the coalescence of the shoals with mattress works so as to concentrate the tidal streams. His aim was only a 15-ft. low-water draft. During the subsequent 40 years there were gradual changes in the shoals and channels which, although slight from a geographical point of view, gave better depths on the bars, but during that time ships were built larger, and it became a regular thing for them to adapt their sailings to the time of high water on the bars. In 1911 the second Engineer in Chief to the Whangpoo Conservancy Board, H. von Heidenstam (now Swedish Minister in Persia), reported on the ultimate necessity for



Mark Beacon on Concrete Caisson in Estuary

improvement of depths on the bars. In 1916 he arranged for a special survey of the whole Yangtse estuary by the Conservancy staff to be made in conjunction with the Chinese Maritime Customs; the latter had already continued the previous work of the British Admiralty in surveying the main sea approaches. Von Heidenstam was then authorised to make a special investigation as to ways and means of improvement, various specialists were consulted and, finally, in 1921, an international committee was convened in Shanghai. This committee included Sir Frederick Palmer, formerly Chief Engineer to the Port of London, Major-General Black, formerly Chief of the U.S. Corps of Engineers, M. Perrier, Inspector Federal des Ponts et Chaussees, formerly of the Suez Canal, M. Ott de Vries, former head of harbour works in the Netherland Indies, Dr. Hiroi, the leading Japanese harbour engineer, and Mr. Hornell, a well-known Swedish consultant, together with Mr. von Heidenstam.

After full consideration of various training schemes (training walls and/or closure of subsidiary channels) and alternative ship canals to the Hanchow Bay, etc., it was unanimously agreed that dredging alone provided a reasonably economic method of attempting to increase the navigable depth in the approaches. The report was before the various Chinese Governments for many years, but finally, in 1930, the Whangpoo Conservancy Board was authorised to do the work. The first of the two dredgers started work in 1935, and has already been described (see " Dock and Harbour Authority," August, 1937, and September, 1937). Some details will now be given of the physical conditions and the results so far achieved.

Description of the Estuary

Whilst tidal rise is still discernible in the winter as far as Tatung (375 miles up the Yangtse from the entrance), reversals of current rarely occur above Chinkiang (200 miles up) and in the summer when the river is running strongly may not occur above Kiangyin (120 miles from the entrance). At the last-named place the river is deep and narrow and rests against a group of hills. This point is for practical purposes the head

The Yangtse Estuary—continued

of the delta, although from a strictly geographical point of view Chinkiang is the real head. Between Chinkiang and Kiangyin the river is very much split up with old bights, but it is wholly recombined at Kiangyin. Fifteen miles below Kiangyin the river splits and again recombines, and at Plover Point (65 miles from the entrance) a definite division into two branches (North and South "Branches") occurs, separated by the Tsung Ming Island, 50 miles long. About the middle of the length of this island the South Branch again splits into the North and South "Channels." This split is only a few miles above Woosung, which is the place where the Whangpoo River, on which Shanghai is situated, enters the Yangtse. These two channels are separated by a chain of shoals, some of which have been reclaimed by dykes for agriculture. Between the individual shoals of this chain, shallow cross channels run and gradual changes are incessant. At about 10 miles landward of the vaguely-defined entrance, all the three main channels (North Branch, North Channel and South Channel) have bars with about 16 to 18-ft. of water at extraordinary low spring tides over a width of about one mile in each channel. The low-water widths of the channels are each about four miles. The South Channel is the straightest, deepest and most stable, and for some years has been the only one used by the larger ocean vessels.

Automatic Tide Gauge in Estuary, with Guard Piles

Near the bar in the South Channel is another split separated by a shoal (The Tungsha Spit, covered about 10-ft. at lowest water), the two arms being termed the North and South Forks. The North Fork (former "Tungsha Channel") is deeper, but the South Fork (former "Fairy Flats") is straighter. Outside the bottom gently slopes to deep water.

The bed and bank material in the estuary is, speaking generally, a fine mud (particles less than 0.1 millimeter in diameter) but at certain places patches of elutriated sand, about one millimeter in diameter, occur, and this sand packs rather hard. The mud is greasy in feel and dries to a very hard biscuit consistency. Its density (wet) is about 1.8 and its void ratio (pore volume to grain volume) nearly unity. The sand may have a wet density of nearly 2.0, and its void ratio is also about unity. Bottom slopes are very flat, but in a bight the side may be as steep as 1 in 3.

The sectional area of the estuary contracts very rapidly as the estuary is ascended, and with it the tidal wave also diminishes. Slight bore effects occur on the shoals. At the extreme mouth (defined here by the high-water lines but not so in regard to the distances previously mentioned which are reckoned from a bow-shaped front tangential to the low water coast line) the convergency or rate of change of width to length is about 2/3. [Note.—In the author's paper "Problems in the Theory of River Engineering," Inst.C.E. Selected Paper No. 71, 1929, the convergency is given as 1/14 which is a clerical error for 12/14. This has now been slightly revised]. The convergency rapidly diminishes according to the logarithmic rate, and is almost zero at Kiangyin.

The low-water section at the outermost part of the estuary is about three million square feet; at the bars, ten miles inward, it has diminished to about two million square feet, and at Woosung, forty miles inward, it is about one and a half million square feet. These figures are the aggregates for the combined channels. At the junction of the North and South Branches above Tsungming Island, seventy miles up, it is about one million square feet, and at Kiangyin, 120 miles up, it is only 350,000 square feet.

The spring tide high-water areas change in an even greater degree from perhaps seven million square feet at the entrance to six hundred thousand at Kiangyin.

Tides

The total flood wave entering during a spring tide at the mouth is about three hundred thousand million cubic feet, diminishing to about two hundred thousand million at the bars, to ninety thousand million at Woosung and five thousand millions at Kiangyin. In entering, it is divided fairly equally amongst the three principal channels.

These figures differ slightly from those published in 1927, which are referred to the high water coast line which is inside the bars. (See "The Great Yangtse Bar," Proc.Am.Soc.C.E., October, 1927).

The run-off of the Yangtse varies from about 250,000 cu. ft. per second at the end of January to about 2,500,000 cu. ft. per second in August. If the run-off in the summer is considered to discharge wholly during ebb tide it may amount to 65,000 millions of cu. ft. in a tidal period, corresponding to a mean non-tidal velocity on the bars of about 1-ft. per second added to the tidal ebb. Nevertheless the flood current is usually as strong as the ebb, but it, of course, does not run so long.

The "vulgar establishment" on the bar is about 11 h. 20 m., e.g., high water occurs about 11.20 a.m. on the day of full or new moon. Spring tides occur on the 3rd or 18th day of the moon, and neap tides on the 10th and 25th days of the moon. Excluding typhoons and very strong winds, the tidal rise of high water above low water of extraordinary springs varies from 8 to 18-ft., but is usually 16-ft. at springs and 11-ft. at neaps. There is a marked "diurnal inequality" which may cause alternate neap tides at certain epochs (e.g., April) to have a high water with only about 8-ft. rise.

The tidal wave advances with a speed of about 20 miles per hour at spring tide up river from the bars, so that a fast ship can almost keep pace with it.

Measurement of Tides

During the investigations that have proceeded since 1917, automatic tide gauges have been established at Kiangyin and Side Saddle (an island about 40 miles outside the entrance). At Woosung a similar tide gauge had been working since an earlier date. Temporary tide poles were read at the shore at certain intermediate places, but the flatness of the shores and the tremendous distances had prevented the attainment of great accuracy in the measurement of the actual tide at the South Channel Bar. As soon as the W.C. Board was authorised to carry out the dredging, arrangements were made for setting up beacons near the bar. Five such beacons, striped to serve also as tide poles, have been established around the bar at distances of about five miles from it, and, in addition, temporary poles and an automatic gauge have been set up nearer to it, so that now fairly accurate observations are possible.

The actual rise may differ considerably from the astronomically or statistically computed value owing to wind. The shallowness of the water causes the wave front to be rather steep, the phase is always somewhat variable, and an uncertainty even in moderate winds of a foot or so still exists.

The following figures will give a good idea of the tidal levels on the main Bar:—

Highest high Water (Typhoon)	22 ft.,	or 18 ft. above ordinary L.W. spring
Standard spring high water ...	16	12
Mean high water	13	9
Highest *low* water	12	8
Standard neap high water ...	11	7
Mean water level	9	5
Standard neap low water ...	7	3
Mean low water	5	1
Lowest *high* water (Typhoon) ...	4	0
Standard spring low water ...	4	0
Lowest low water	0	-4

There is an annual variation due to wind, barometric pressure and run-off with about 1½-ft. range on the bar, so that the winter (January-February) levels (excepting the extraordinary cases H.H.W., H.L.W., L.H.W. and L.L.W.) may be from 0.25 to 1.0-ft. lower, and the summer (August-September) levels from 0.25 to 1.25-ft. higher.

Typhoons may raise the normal high-water level by as much as 4-ft. and the low water by as much as 6-ft. Strong winds from inland, which may occur in December, may lower low-water levels by 2-ft.

The direction of the currents has been observed at various places in the estuary, and since the dredging commenced has been studied very carefully. In the South Channel the main flow over the bar is almost parallel to the South Fork, in spite of the steepest "thalweg" or valley line following the North Fork. Small bore effects occur over the shoals and patches of "tide rip" or "chow-chow" water also occur there. Maxi-

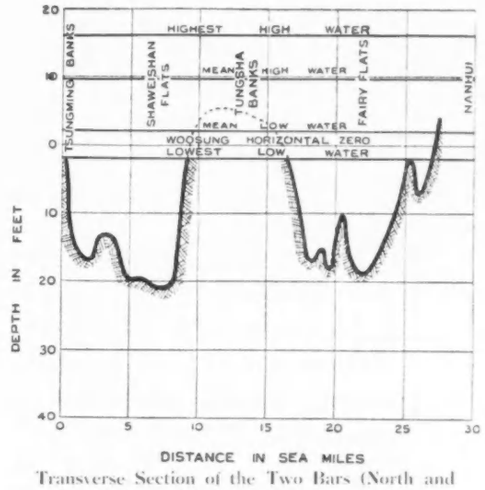
The Yangtse Estuary—continued

mum velocities at the bar may reach 10-ft. per second at strong spring tides, but above the bar the current rarely exceeds 6-ft. per second.

During storms the seas are usually " short," but occasionally there is a fairly strong swell. The loss of time in dredging due to weather (including fog) averages less than 15 per cent.

Silt

In the Yangtse above the tidal reaches the quantity of silt suspended fluctuates from 100 to 1,000 parts by weight per million according to the season. The average is about 500. As the volume of water is enormously greater in the summer than in the winter, the effective average corresponds to the actual



Transverse Section of the Two Bars (North and South Channels). North Branch not shown

value for a medium high stage and not to the value for the mean stage.

In the reaches just above the estuary, owing to the dilution by tide water, the silt content is rather lower. In the estuary itself the silt content may rise to as high a value as 2,000 parts by weight per million, owing to the high tidal current velocities. This indicates that immense volumes of silt are continually shifting about in the estuary, eroded at one place and deposited at another.

The silt minerals have a density of about 2.5, and in the consolidated form contain about 50 per cent. by volume of interstices so that 500 parts per million corresponds to 200 parts per million by volume of solid mineral and about 400 parts per million of deposited alluvium. Incidentally, this indicates that the volume of mud (half water) is twice the volume of the original rock. Of course, as the mud consolidates gradually the equality of volume will eventually be restored, but not until the mud has reached a very low level after many millenia.

Salinity

On the bar the density of the water varies from unity to 1.02, according to the tidal currents. The latter part of the flood is necessarily fairly pure sea water (density 1.025), but in the average the density is less than 1.01. By mixing of the tidal streams salinity diffuses during the winter as far up as Woosung. Two Dutch engineers (M. Jolles in a report to the Board, and M. Canter Cremers in the D. & H.A., Sept., 1923) have raised the question of colloidal precipitation of the silt on the bar by sea salt. (See the author's paper, Inst.C.E. Selected Paper, No. 52, 1927, " The Constitution of Clay-Mud "). Judging by the rather abrupt termination of the coffee-coloured water outside the estuary, such a precipitation effect does occur, but the currents on the bar are so strong that it is doubtful if this plays much part in the formation of the crest of the bars and it is more important on the continental shelf.

Bed Structure and Foundations for Works

In the Whangpoo River, the bed and banks of which consist of old delta material, all under-water dyke-work is built on foundation layers of willow fascine mattresses, weighted with rubble stone. Such mattresses have also been used in the estuary for the support of the concrete caissons on which the mark beacons have been erected. The largest beacon (on the Tungsha Spit which separates the North and South Forks) was placed without a mattress, as the currents were very strong and the bed appeared to be of firmly consolidated sand. The weight (less buoyancy) was over 100 tons, and the base area was about 900 sq. ft. After a few hours the caisson sank rapidly by 6-ft. or so, and has since remained. The rotary scour of the currents appears to have been responsible for this drop, and has caused some trouble even where the load is much smaller and where mattresses have been used.

Mattress work of this kind is used quite successfully in the Whangpoo for submerged groynes and channel closures, and could doubtless be so used in the estuary but, owing to the depths of water involved, if rubble or block training works were built on it the mattresses would need to be multiple and wide. Such works, to produce any important training effect in the estuary, need to be many miles long, even as groynes, and must be finished at wave level with large concrete blocks, so that the cost appears prohibitive.

Wrecks generally work themselves into the bed and practically disappear, but this is not always the case, depending on slight variations of the bed material and on the alignment of the structure with the direction of the currents. Chains, anchors, a large breech-loading gun and other heavy objects have been dredged from within 6-ft. below the original bed surface, showing that such objects do not descend very deeply.

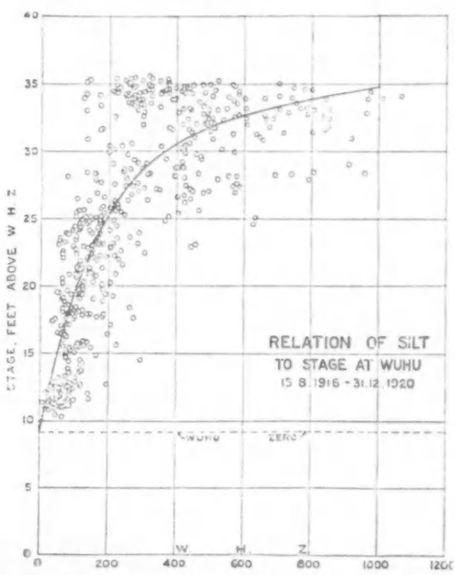
Meteorology

Weather observations at Zikawei (Siccawei) Observatory near Shanghai and at Gutzlaff Island just outside the estuary, are available for many years, and an elaborate system of interrelation between the observatories at Zikawei, Hongkong, Manila and Japan, combined with information from ships at sea, enables typhoon and depression warnings to be given. During a typhoon gusts up to about 150 miles per hour can occur, and since this air is often laden with 100 per cent. of its weight by rain drops a pressure of as much as 100 pounds per sq. ft. may occur on a vertical exposed surface. Winds exceeding Force 5 occur on the bar about 27 per cent. of the time, rising to over 40 per cent. in December and January, with calm periods in June and October. Force 6 and stronger occurs about 12 per cent. of the time and Force 7 about 2 per cent.

Although the prevalent wind is easterly, in the winter there may be strong blows from the N.N.W. and N. tending to drive the water out of the estuary. The summer winds are generally from S.S.E. or S.E., and tend to raise the water in the estuary. Since these synchronize with high and low barometer respectively, and with weak and strong river discharge respectively, there are, as already mentioned, perceptibly higher water levels in the late summer.

Temperature varies between freezing and 100 degrees Fahrenheit. Frost is not usually prolonged more than one or two days and is rarely sufficient to affect steam deck gear, although it has been known to do so.

Fog occurs on the bar about 6 per cent. of the time, mostly from February to June; it generally clears before 10 a.m., but may occasionally persist for a day.



Silt Content at Wuhu (300 st. miles up river from entrance)

The Dredging Project

The 1921 Committee recommended that an attempt should be made to serve 33-ft. drafts and considered that for the time being a lowest low-water depth of 27-ft. on the bar should be aimed at. This means that with a rise of 9-ft. (allowing 3-ft. for " squat," pitch and margin) a 33-ft. draft ship could pass safely. 9-ft. rise corresponds to mean water level so that such ships could then pass at all high waters and generally more than 50 per cent. of the time. Smaller vessels could, generally speaking, pass at all times, and still larger ships could pass at normal high waters.

The charts for many years were studied with particular regard to the development of the steepest valley line, and it was finally

The Yangtse Estuary—continued

decided in 1934 that the dredging line should follow the South Channel down to the bar and then go on into the North Fork. This was not the straightest route, but it appeared to be the most stable and involved smaller volumes of excavation than the more direct South Fork. The whole length of the cut would be about 25 miles, but in much of this there was only about 3 or 4-ft. of deepening required, whereas in the South Fork the average deepening required over the whole length was 5 or 6-ft. The width of the cut was initially decided at 600-ft., but it was hoped that side slip and erosion would widen it further. One great objection to the North Fork was that the currents run obliquely across the cut into swashways over the shoals between the North and South Channels, which would somewhat hinder dredging and prove annoying to shipping which must bear towards the tidal stream and occupy a considerable fraction of the channel width. It was considered that this disadvantage would be sufficiently offset if appreciable increase in depth could be produced and that there was some hope that, aided by dumping of the dredged spoil, the swashways may later on close up.

Work started in July, 1935, on the crest of the bar, somewhat north of the shipping route, but a very hard patch of sand was struck and it was decided to move the cut a little to the south where the sand patch was less extensive. Since September, 1935, up to the outbreak of hostilities about 10 million cubic yards of in situ material has been removed, and although part of the cut has partly refilled the actual depression formed (which extends laterally far beyond the dredging lines) shows very little *net* accretion has occurred, and now on the old crest of the bar where there was 18-ft. or so at lowest low water there is about 22-ft. over a length of some three miles and a width of about half a mile. In certain parts of the cut the ultimate desired depth of 27-ft. was actually reached. In fact, the effective bar is now the upper part of the cut which has not yet been dredged. At this stage of the work, of course, a suspension of the dredging will be very harmful to the stability of the cut.

In order to mark out the cut and exclude navigation from it during the dredging two lines of three lighted buoys of the standard Pintch type were put down about 1½ miles apart, the two lines being separated by about 1,200-ft. These buoys are maintained in position by heavy moorings, and are kept under frequent observation by a special survey ship. The new beacons previously referred to served as fixed marks for the restoration of the buoys to place after storms. Owing to the undermining of the moorings by side slip of the bed towards the cut, this restoration has rather often been necessary.

The dredged material has been dumped in the blind end of the North Fork in the hope of choking it up, but so far little change has occurred there, the material being apparently washed by the flood tide into the swashways between the shoals.

The record daily output has been about 38,000 cubic yards of in situ spoil.

It is hoped that a second dredger, now under construction in Germany, will be able to co-operate in the work from early in 1939, and that the two will have a joint annual output of some ten million cubic yards of in situ material. Allowing 50 per cent. for re-accretion during the work, this should enable the project to be realised in a few years thereafter, and a reduced programme of dredging should serve to maintain it. A continuous watch is being kept on the estuary as a whole so as to anticipate the effects of any general natural change which may develop.

Already the improved marking, better tidal information and deepening of the bed beyond the mark buoys have been of benefit to shipping. The growth of draft and total tonnage anticipated by the 1921 Committee has been more than fulfilled so that the steady prosecution of the work is intimately related to the future prosperity of China's foreign trade in general and the welfare of Shanghai in particular.

Remoter Future of the Estuary

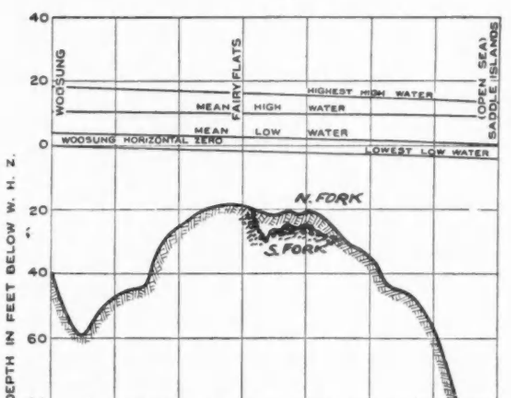
The immense volume of mud which comes down the Yangtse (some 500 million cubic yards per annum) is deposited partly in the neighbourhood of the estuary and partly (as regards the finer material) on the slope of the continental shelf further out. The slope towards the Saddle Islands is only about 1 in 2,000, and it is computed that by the year 4,000 A.D. the shore will reach those islands, the mean advance of the coast being about one mile in fifty or sixty years. Incidentally, it should be observed that this rate tends to decrease as the "front" expands, but this is not an important factor until the advance has proceeded a good deal further.

The bars will necessarily advance in a similar manner, and in this period the mean water level at Woosung will rise by 2 or 3-ft. There are indications of this process of rising water level having occurred within the estuary in the past, the level of the alluvium between the present river dykes and older inner dykes being higher than the general land level.

This advance of the coast will, however, not be a simple process of marginal accretion. The cluster of shoals which separate the North and South Channels will doubtless eventually accrete into a main island like Tsungming Island, and the erosion of concave shores will cause both islands gradually to change shape, as Tsungming Island has already done in the last millenium. New shoals will form outside and new bifurcations will appear. Such lands as may be reclaimed on the present or future shoals will have little use except for agriculture, so that it will not be worth while to protect them by training or revetment unless they are directly related to the navigable channels.

M. Brandl, a much-experienced engineer from the Danube, who was for some time connected with the Hydraulic Engineering Bureau of the National Economic Council in Nanking, favours such training or coalescence work, but it seems very doubtful if it can be economical within the outer parts of the estuary where the land is of small value and the dimensions are so enormous that even the navigational interests would shrink from the terrific costs.

Fears have been expressed from time to time that at a period when the flood dykes happened to be broken a few miles below Kiangyin on the North shore (or even between Chinkiang and Kiangyin), the river might break through to the north of the present channels, which it might then abandon. It is pointed out that the direct distance to the sea is less in that direction and that the land is low and easily flooded.



Longitudinal Profile of S. Channel Bar

Such fears seem unfounded as the distance to deep water in that direction is no less than that along the present route, the land is not low in relation to the present main channels, and there are numerous obstructions in the area which would hinder the development of a rapid flow in the broad lake which might result from a very bad dyke break. Furthermore, the tidal capacity of the present channels is very great and would maintain them to an extent which would ensure the bulk of the run-off continuing to flow through them.

The lateral spread of the finer silt outside the estuary, due to tides and marine currents, tends to keep the fan of the delta wide, and there are shoal areas to the north of the entrance, partly due to the former discharge of silt from the Hwai and Yellow Rivers, so that the general trend of the sea trough is towards Japan. Doubtless lateral breaks may occur at a later date in the history of the delta, but they appear improbable for some centuries to come, and they could for long be averted by proper dyke maintenance and channel control. The Hangchow Bay, which lies south of the delta, is gradually silting up, also due to silt from the Yangtse, but its large tidal capacity will doubtless keep it in existence for several millenia, but with decreasing depth. Several projects for ship or lighter canals to a "port-de-vitesse" on the Hangchow Bay have been considered, but a long view is rather unfavourable to this idea, especially as the tidal currents there are very strong, especially in the western part of the bay where the famous bore develops in the mouth of the Chien Tang River.

Information concerning the Yangtse River

There is now a considerable volume of literature on the subject of the Yangtse. The Whangpoo Conservancy Board has published three reports on the estuary (general, geological and hydrological), but these are now out of print and can only be seen in certain libraries. The Yangtse River Commission, founded in 1922, has produced a series of annual reports, which give a great deal of hydraulic information concerning the river above the estuary. Up to about 1932 these reports are in English. Messrs Coode & Nijhoff have made a few remarks on the Yangtse in their 1936 Report to the League of Nations on Hydraulic and Road Questions in China. Professor Geo. B. Cressy has produced an excellent book on the physical

The Yangtse Estuary—continued

geography of China, entitled "China's Geographic Foundations," which includes some interesting and useful information as to the Yangtse and its alluvial plain. The paper by von Heidenstam to the American Society of Civil Engineers referred to above contains valuable data, and the present writer has several papers to the Institution of Civil Engineers, Junior Institution of Engineers, Engineering Society of China, and the Royal Asiatic Society (North China Branch), which touch on the matter. As to the dredging in the estuary, the work in the Shatt Al Arab in the Persian Gulf and that in the approaches to Buenos Aires afford the best comparisons.

Almost 10 per cent. of the world's population lives in the basin of the Yangtse, and the regulation of the sea approaches to this important area is a problem of first-class significance.

Department of Scientific and Industrial Research

*Summary of Report on Driving Reinforced Concrete Piles**

The Department of Scientific and Industrial Research has just issued a report on an investigation into the causes of failure, and methods for preventing damage in reinforced concrete piles during driving. The work was carried out at the Building Research Station with the collaboration of the Federation of Civil Engineering Contractors, and was initiated as a direct result of difficulties experienced while driving piles through hard strata; it is being continued in co-operation with the Institution of Civil Engineers.

Pile Foundations in London Area

In and around London there are many building sites where the ground consists of alluvial or made-up soil of very low bearing power for perhaps 10-ft. to 30-ft. from the surface. Below this a stratum of hard, compact gravel is to be found varying in thickness from perhaps a foot or two to 20-ft., a variation of this order occurring over any one site. Below the gravel a stratum of comparatively soft earth of low bearing power is again found, and at a greater depth still a hard compact clay is reached. In designing structures for such sites, the engineers, owing to the uncertain thickness of the gravel belt, have, in many cases, thought it advisable to found below the gravel on the hard clay. In penetrating the gravel very hard driving conditions are experienced, and it had been found difficult to construct pre-cast piles of sufficient strength to withstand the very severe conditions. Information as to the effect of driving conditions on the behaviour of a pile was scanty, and what was available was not correlated on the basis of a rational theory. For instance, no recognised standards existed for determining the correct weight of hammer, height of drop or amount of head packing for a given pile, and there was no method of estimating the effect of the conditions at the foot on the stresses in the pile.

Empirical rules based upon experience provided a rough guide for practical use, but could not be relied upon to indicate, for any known set of conditions, whether troubles would occur or not, and the only method of deciding whether piles would stand up to specified conditions was by actual driving.

The experiences of contractors were interpreted in terms of a static theory, assuming instantaneous propagation of stress throughout the pile. The velocity of stress propagation in a reinforced-concrete pile is approximately 12,000-ft. per second, and any theory neglecting this fact was bound to lead to erroneous conclusions.

Nature of Research

The research involved: (1) an examination, both analytical and experimental, of the nature and magnitude of the stresses induced in piles by impact; (2) a study of the effect upon impact resistance of the methods employed in the design and manufacture of the pile; (3) the development of methods of indicating dangerous conditions during driving.

A piezo-electric method of recording the dynamic strains at selected positions in the test pile was developed. Piezo-electric quartz gauges were embedded in the pile during the casting operation, and, during the test, were connected by suitable amplifying equipment to a cathode-ray oscillograph, with which photographic records were obtained.

Numerous tests were carried out on model piles, and the applicability of the results to the full scale was confirmed by similar strain measurements on large piles driven under contract conditions.

The impact resistance of piles was studied by destruction tests on 15-ft. piles driven under controlled conditions.

The experimental investigation confirmed the mathematical analysis in all its main conclusions, and showed that it could be applied to estimate the stress at any point under known conditions.

Important facts emerging from the research are:—

(1) Driving failures are due in the majority of cases to excessive compressive stress, and the probability of failure is largely determined by the value of the maximum compressive stress.

(2) For most driving conditions, the stresses at the head are higher than those elsewhere in the pile, and for piles more than 30-ft. long are practically independent of the set of the pile and the conditions at the foot.

(3) Under hard conditions of driving a wave of compression is reflected from the foot of the pile, and the stresses at this point have a theoretical maximum, assuming no friction or propagation loss, equal to twice the stresses at the head. The greatest value recorded was 50 per cent. greater than the head-stress.

(4) The foot-stresses were shown to depend on the total movement at the foot, not on the set as ordinarily measured, but on both the permanent set and the temporary elastic earth movement at the foot; an "equivalent elastic set" taking both into account is defined and used in calculations for determining the foot stresses.

(5) A small set per blow is, in itself, no certain indication of high foot stresses; the small set must be accompanied by the concentration of driving resistance at the foot of pile, as when the pile penetrates a stratum of gravel.

(6) Under certain conditions of easy driving, high tensile stresses may be set up at the middle of the pile, but as a cause of failure they have been shown to be of little importance.

(7) The tensile stresses due to flexural vibration caused by a single impact delivered eccentrically have been shown to be small. There is a possibility of increased stresses, however, where the number of hammer blows per minute is large; resonance may then occur, and the flexural vibrations may build up to a dangerous extent.

(8) The conditions at the head of the pile, namely, the dolly and the packing in the helmet, play a fundamentally important part in determining the stresses, particularly at the head; the lower the stiffness of the head cushion, the lower are the stresses in the pile. For piles over 30-ft. long the head stress is almost completely dependent on the packing stiffness and the weight and height of fall of the hammer.

(9) The cushioning effect of the head covering is chiefly due to the packing in the helmet, and the materials used as packing in practice show a continuous increase of stiffness under repeated impact, resulting in a corresponding increase of stress in the pile. At the head the stress at the end of driving may be double that at the beginning, when the packing was new. Many cases of head failure may be attributed to this effect.

(10) Dangerous local concentrations of stress may result from unevenness in placing the packing material on the pile head.

(11) The impact strength of concrete may be only 50 per cent. of the cube compressive strength. In hard driving the maximum compressive stresses may exceed 3,000 lb. per sq. in.; it is therefore clear that only high-strength concrete can be expected to stand up to hard driving conditions, and that with existing driving methods, it is necessary to work to low factors of safety.

The Design and Manufacture of Reinforced Concrete Piles

The tests have shown that the amount of longitudinal reinforcement does not greatly affect the ultimate driving resistance of a pile, provided the latter is initially free from harmful transverse cracks. If sufficient longitudinal reinforcement is used to enable the pile to be transported and pitched without fracture, it is unlikely that failure due to insufficient reinforcement will occur during subsequent driving.

The amount of lateral reinforcement, on the other hand, profoundly affects the impact resistance of a pile, particularly at the head and toe. For piles subjected to hard driving it is recommended that for a length from the extremities of $2\frac{1}{2}-3$ times the external diameter of the pile the volume of lateral reinforcement should not be less than 1 per cent. of that of the gross volume of the corresponding length of pile. The diameter of the ties should conform with the usual practice for reinforced concrete and be not less than 3/16-in. or one-fourth the diameter of the main bars, whichever is greater. The minimum spacing of the ties at head and foot should be such as to provide ample facility for placing the concrete.

For sites where driving is easy and resistance is chiefly due to skin friction, it is still advisable to strengthen the head.

* Building Research Technical Paper No. 20. An Investigation of the Stresses in Reinforced Concrete Piles during Driving. Published by H.M. Stationery Office, price 3s. net.

Department of Scientific and Industrial Research—continued

The cover of concrete over the reinforcement should be decided solely from consideration of the protection required by the steel, and should therefore be as in ordinary reinforced concrete practice.

Reinforcement by means of external bands placed at the head of the pile was found to increase driving resistance very considerably. A similar form of strengthening at the toe will also be useful in cases where very hard driving is to be encountered.

Of the types of cement investigated, normal Portland, rapid hardening Portland, and high alumina, there is no evidence from the tests at the Building Research Station to show, considerations of hardening period apart, that any of these types is definitely superior to the others.

Within the range of mixes investigated, no great increase in impact strength is obtained by increasing the cement content beyond the proportions by weight of 1 part of cement, 1½ parts of sand and 3 parts of aggregate. A 1:2:4 mix, on the other hand, is considerably weaker than 1:1½:3. This trend is similar to that already known to exist in reference to static compressive strength, and appears to apply generally to all Portland cements. It is not at present known whether high alumina cement concrete also exhibits this tendency, or to what extent, in the case of all types of cement, it is dependent upon other factors, such as the grading of the aggregate.

No evidence is available at present to show that any particular type of aggregate possesses marked superiority.

The water-cement ratio should be kept as low as possible, consistent with proper compaction of the concrete.

The influence of wet curing upon impact strength is well defined. It is recommended that wet curing should be applied for as long as is practically possible; unless conditions of driving are easy, for Portland cement concrete this period should be not less than 14 days.

The impact tests have shown that the impact strength of the concrete may be as low as 50 per cent. of the cube crushing strength. Since, in hard driving, maximum compressive stresses exceeding 3,000 lb. per sq. in. can be set up, a concrete of crushing strength exceeding 6,000 lb. per sq. in. is necessary in the circumstances. For easy driving conditions the impact strength should be not less than 2,000 lb. per sq. in., that is, the concrete should have a crushing strength of not less than 4,000 lb. per sq. in.

Handling Stresses

Great importance is attached to the avoidance of serious transverse cracks during handling. This is not because cracks of this nature are likely to impair the strength of the piles through corrosion over a period of years. It is known that under most conditions the cracks are satisfactorily sealed by further hydration of the cement during the later stages of hardening. The danger lies in the fact that under severe driving conditions a wide transverse crack may prove to be the starting point from which the ultimate failure of the pile begins.

Driving Conditions

It is important to realise that normal factors of safety, as employed in other branches of engineering, do not generally apply to the driving of reinforced-concrete piles by present-day methods; the margin of safety is in many cases small, and is sometimes non-existent. It has been stated previously that the impact-strength of concrete varies between 50 and 80 per cent. of the cube compressive strength. Since it is impossible at present to define the relationship within closer limits, a maximum stress of 50 per cent. of the cube compressive strength may be regarded as representing what may be termed a driving factor of safety of unity.

As the margin of safety is frequently very small, it is important that reinforced concrete piles should be driven by the best possible method.

Within the range of conditions investigated, it was found that the most favourable conditions of driving, represented by the value of the factor: $\frac{\text{set}}{\text{maximum head stress}}$, occurred without exception when the heaviest hammer was used in conjunction with the head-cushion of lowest stiffness, the height of drop being adjusted to give a safe stress. There is reason to suppose that this rule can be applied generally, and is virtually independent of the type of ground into which the pile is driven.

Since in all cases the heaviest possible hammer is required, the choice of hammer weight depends only upon consideration of plant available. It is suggested that a reasonable minimum for the weight of the hammer is obtained by making the value of the ratio $\frac{\text{weight of hammer}}{\text{weight of 1-ft. of pile}}$ not less than 30. This gives for 12-in., 14-in., 16-in., and 18-in. sq. piles hammers of 2¼, 3, 3½ and 4¾ tons respectively. Of the types of hammer in common use—drop hammers and single-acting steam hammers—there appears to be no type possessing outstanding advantages. In all cases there is a certain loss of kinetic energy, due to frictional and other causes, and it is usual to make allowance for this factor when calculating the striking energy of the hammer. A head-cushion should always be used. The best way of using the materials at present available would be simply to place packing on the head of the pile, but owing to the difficulty of retaining the packing in position it is generally necessary to use a helmet. A light helmet is to be preferred to a heavy one, as a heavy helmet is likely to cause more rapid deterioration of the dolly. The interior surfaces of the helmet, and more particularly the surfaces parallel with the head of the pile, should be truly plane. The helmet should be well-fitting and should be prevented from abrading the sides of the pile by layers of material, such as sacking, placed over and around the head. The problem of packing is complex, for, during the course of the investigation no form of packing was encountered which satisfied completely the theoretical requirements, viz.:—

(1) Low stiffness.
(2) No increase of stiffness during driving.
(3) Low cost in relation to durability.

The packing tests have shown two materials which satisfy the first two requirements. The first is rubber, which, however, has the disadvantage that room must be allowed for lateral expansion; it cannot therefore be used in ordinary helmets, but might be used with a helmet of suitable design. The second material is asbestos fibre, which also fulfils the first two requirements. Its first cost is rather high, however, and it remains to be proved whether the material is of practical value. Of the packings in common use, tested in the impact machine, sack-cloth exhibited the best characteristics. Whatever material is used, it is advisable that the layer in contact with the head of the pile should be of soft material, so that any small irregularities in the pile-head may not be the cause of failure.

The Technical Paper includes charts which enable the driving stresses in a pile to be deduced for a wide range of conditions, and a simplified series for use in practice. These can be employed to determine the correct height of fall of the hammer under given conditions and to assess dangerous conditions at the foot of the pile.

Port of London Developments

As a further and ultimate step towards the complete reorganisation of the Royal Victoria Dock, the Port of London Authority have authorised the erection of five 3-storey warehouses, five miles of railways, roads, drainage and other contingent works at the north side of the dock. Each of the new sheds will have a quay frontage of 504-ft. and a width of 150-ft. The ground floor of the sheds will be used for transit purposes, i.e., the sorting, etc., of incoming cargo and lotting ready for shipment of export traffic. The upper floors will be used for storage purposes, and will increase the warehousing capacity of London's docks by approximately 100,000 tons. The work is anticipated to take rather more than two years to complete, and will cost nearly £730,000.

Alterations are to be carried out to the cranes and railway tracks at the South side, Royal Albert Dock, preliminary to the completion of the electrification of the whole dock. The work will be arranged so as to cause the minimum of interference with the normal use of the berths.

In order to provide suitable discharging facilities for the s.s. "Dominion Monarch," a new vessel to be put into commission between London and New Zealand by the Shaw, Savill & Albion Line in February next, the Port Authority have decided to install eight new electric quay cranes with a lifting capacity of three tons each, and to provide 18-ft. gauge rail tracks for the cranes on the north quay of the King George V. Dock. The radius of the new cranes will be 80-ft., or about 20-ft. greater than most of the cranes in use at the docks.

Extensive work is thus in progress in all three sections of the Royal Docks system, the largest docks in the world. At these docks alone no less than 7,374,769 n.r.t. of shipping was discharged and loaded last year. The complete modernisation of the Royal Victoria Dock has been necessitated by the greatly increased average draft of vessels using the port. Last year a record tonnage of 62,645,758 n.r.t. of shipping arrived and departed from the Port of London, and over 44,000,000 tons of goods were handled.

Improvements are to be made at Tilbury Dock for the accommodation of the vessels of the Orient Line. To facilitate the discharge and distribution of chilled meat, a new loading platform for road vehicles and improved road access are to be provided. At the Orient Company's export berth at Nos. 15 and 16 Sheds, Tilbury Docks, where the traffic has considerably increased, the railway bank in the rear of the sheds is to be extended to accommodate a larger number of trucks and certain other work to facilitate passenger traffic is to be undertaken.